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THE CENTRAL TELEGRAPH OFFICE, PARIS.

WHATEVER has been said about it, the employes of the post and telegraph offices have never had any intention of going on a strike, but the sole announcement of such a fact has sufficed to cause the liveliest apprehension throughout the entire country. This is because a strike of these persons would in nowise resemble those other strikes that injure merely a corporation and a limited number of people having need of the latter. Without counting the disturbance introduced into the commerce, industries, and finances of the country, there is not an inhabitant who would not experience some injury or annoyance from a general, or even partial, strike of the employes of the post and telegraph offices.

After various turns of fortune, this agitation now seems to be concentrated in the telegraph offices of Grenelle Street, that are usually designated as the "Central." It has seemed to us that on this occasion a few explanations of the operations and importance of the Central would be read with interest.

The building is located at No. 103 Grenelle Street, and communicates with the general direction of post offices by an underground passage that runs under the court of the Minister of Commerce's Hall, and thus ends at No. 99 of the same street. On crossing the threshold of No. 103, one's view is arrested by a sort of high tower inclosed in the modern structures. This tower, constructed in 1840, and the stones of which have recently been scraped, was the old central office of the Brothers Chappe's aerial telegraph. It is here that were centralized the official dispatches of the five great lines of Lille, Strasbourg, Toulon, Bayonne, and Brest. For the south, the signals were transmitted to Saint Sulpice, Montlhery, Villejuif, etc., and, for the north, to Saint Eustache, Montmartre, Ecouen, Saint Martin du Tertre, etc.

The upper part of the tower is now unoccupied. The main door, reserved solely for the female employes, gives access to a superb vestibule. In the first story, in the office of the old director-general, are found the chiefs of section. In the second story there are retiring rooms for the employes who work at night.

The "manipulating" body of the Central comprises 543 men and 414 women. It is distributed through three halls, each having an area of about 600 meters. The *personnel* is divided into two brigades, each having a section chief at the head of it. The latter is aided by sub-chiefs and chief clerks.

These brigades work successively from 7 to 11 o'clock in the morning, from 11 to 6 in the afternoon, and from 6 to 11 at night. For the night service, from 25 to 30 agents of each brigade are employed. These obtain ¾ of a franc per hour from 9 o'clock till midnight, and 1 franc per hour from midnight till 7 oclock in the morning.

TELEGRAPH HALL OF THE CENTRAL OFFICE, PARIS.

The hall on the ground floor is reserved for the lady telegraphers, who attend exclusively to the business of the stations of Paris, of those of the suburbs, and of those of some provincial cities that have as yet only the Morse apparatus. In fact, this latter is reserved especially for the ladies, as being less fatiguing. Their hall contains 225 of these apparatus. However, some time ago the Hughes apparatus was given to them, and of these they now have 28.

In the first story are two halls reserved for the men. In the first of these, called the "Old Central," are the services of the international telegraph, of the press, of forwarding and classification of telegrams, and of the pneumatic tubes.

These latter are attended to by special employes, 14 in number, who are styled "tubists." There are 16 apparatus—eight to each of the two parallel rows that are very accurately represented in one of our engravings. The vacuum is kept up in the tubes by steam pneumatic pumps located in the cellars of the central office.

A "train" starts or arrives every three minutes. It consists of a tin tube in which are placed the telegraph cards, and which is inclosed in a thick rubber sheath.

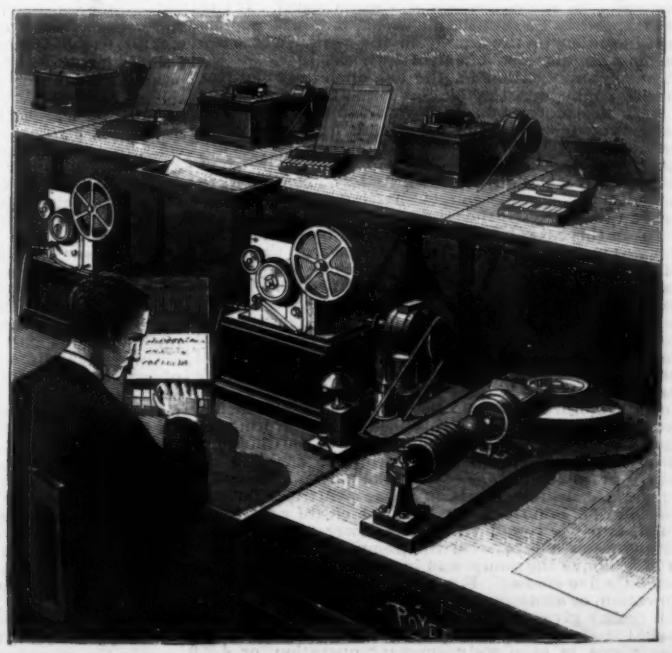
The tubist is notified of the arrival of a train by a bell. He then depresses a sort of lever that is situated in front of each apparatus, and which controls a valve that closes the air tube. He thus opens a small closet which the train has just entered, deposits the latter in receptacles standing to the right of the apparatus, closes the box, and raises the lever. The telegrams are soon collected by a "bouliste"—the term applied to 77 employes, young boys and old men, who do nothing but run from one apparatus to another and gather up the dispatches, etc.

The second hall of the first story is called the "New Central." This is represented in our first engraving. Large windows allow light and air to enter it during the day, and at night it is lighted by fifteen elegant chandeliers, each provided with five gas burners, designed to be replaced by electricity if the gas gives out. This hall is divided by a central alley. To the right are the Hughes apparatus, and to the left the Baudot ones. Here a feverish animation ever exists, amid a perpetual noise of bells and of incessant tic-tacs that impress one's nervous system very disagreeably.

The apparatus employed are 128 Hughes, 2 Wheatstone, and 11 Baudot. Thanks to the Baudot apparatus, from seven to nine operatives can work upon one line. In measure as this line gives the signals, a "distributor" to the right of the operator distributes them between the seven or eight colleagues.

The electricity is furnished to all these apparatus by about 1,000 pile elements, which are stored in a vast hall in the basement. The glass vessels containing the zinc that dips in a solution of sulphate of copper are placed in a line upon a long wooden table, and above the latter there are boards along which run the wires from the piles. All these wires radiate in two circles upon two boards that correspond to similar ones on the ground floor and first story. Each ray of this sun, so to call it—a ray consisting of a telegraph wire—carries the number of its pile and the number of the

THE WHEATSTONE APPARATUS.



THE BAUDOT APPARATUS.

apparatus that it connects with. In the center of the room containing the piles, which are about 500 in number, is a large basin fed by several cocks, in which five or six men are constantly washing and scraping the zincs and vessels.

In conclusion, we shall give a single figure to show the importance of the Central. It receives and sends 60,000 telegrams every twenty-four hours! This is exclusive of the voluminous correspondence of the press, which is transmitted by special wires, rented or ceded. —*L'Illustration.*

A BASIS FROM WHICH TO CALCULATE CHARGES FOR ELECTRIC MOTOR SERVICE.*

By H. C. LUFKIN.

THE theoretical side of the electric motor question has been very ably presented to and discussed by this Association, but thus far the practical side has been somewhat neglected.

It will be my purpose in this paper, if possible, to show that there is a general average controlling the use of machinery which it will be safe for electric light and power companies to follow in making their charges for motor service, rather than adopt an arbitrary price per horse power, regardless of the character of service required of the motor.

I have arranged what might be called a power curve, representing the approximate average actual service in electric motors in connection with the several classes of work.

This curve is calculated on motors which are only of sufficient capacity in each case to carry the full load. If the motor should be larger than is necessary to drive the machinery, the percentage of actual service will of course drop below that shown in the diagram.

By adopting a basis of averages which shall be general among members of this Association, the charges for a constant horse power of current may vary with the circumstances of its first cost in each case, but the general classification of motor service may be a comparatively fixed rule. I am not prepared to say that this is the best plan to follow, but respectfully submit the following as a possible solution of the frequently asked question, How shall we charge for electric motors?

EXHAUST FANS: First on the list of power consumers is the exhaust fan, taking it in average use. There are, however, circumstances under which its use will be limited to as low as 70 or 75 per cent. of its contract hours of service; as, for instance, in a dining room it may be cut out except during meal hours, or entirely cut out on cool days. In places of this description, however, its contract use is usually limited to three or four months in the year, and other than electric power is, by circumstances of first cost and inconvenience, but a feeble competitor. The first four applications on the accompanying list, viz., exhaust fans, blowers, ceiling fans, and fan outfits, are all more or less subject to the foregoing conditions, and therefore current supplied to motors for these purposes commands the maximum price per horse power. One important feature in the installation of ceiling fans is the countershafting to the motor.

In one recent case we had a complaint from a customer that the ½ h. p. motor sent him would not drive two ceiling fans, and that the motor must be defective, and should be return it for repairs. We immediately sent a representative to find the difficulty, which was found, as is usual in such cases, in the countershafting, or rather the want of it. The 3 in. pulley on the motor was connected to a 6 in. pulley on the line shafting. The rated speed of the motor was 2,000 revolutions, and had it been able to develop this speed, would have driven the line shaft 1,000 revolutions and the fans a relative speed. To accomplish this would probably require a motor of 3 or 4 h. p. The line shafting driving ceiling fans usually runs about 75 revolutions. To give this speed on the line shaft with a rated speed of 2,000 on the 3 in. pulley of the motor would require a countershaft with a 24 in. pulley belted to the motor. On this same countershaft should be a 5 in. pulley belted to a 15 or 16 in. pulley on the line shaft. Fully three-fourths of the trouble found in electric motors arises from improper shafting and belting. The average make of 30 in. exhaust wheel, a ½ h. p. motor should drive at about 400 revolutions. Say then the speed of the motor is 2,000 and the pulley 3 in., it would require a 15 in. pulley on the fan to do the work; a 36 in. wheel requires 1 h. p. to develop the same speed. If the motor speed is 1,800, the pulley 4 in., it would require an 18 in. pulley on the fan to do the work. These are the most popular sizes of exhaust wheels.

The next application on the list, open tank elevator pumps, commands the highest price for current per h. p. in the motor of any elevator application. The methods of operating the open tank hydraulic elevators in question are undoubtedly familiar to you all. Instead of the usual steam pump, a power pump of some approved design is substituted and connected to the motor by suitable countershafting to give the required revolutions at the pump. The regulation of the motor in this case should be controlled by the position of water in the lower tank, as in the case of the steam pump. And in this connection let me suggest the necessity of great care both in installation and insulation. On all installations in basements and cellars, or elsewhere, where there is the slightest tendency to dampness, raise the motor off the floor on a suitable frame or stand, and build around it, on all sides of possible approach, a low platform, using glass insulators as legs or standards to support it. So arrange this that the motor or its connections cannot be reached except when standing on this insulated platform, and the liability to a shock will be reduced to the difference of potential between the terminals of the machine. To return to the subject. Let us take for an illustration an elevator using 120 gals. of water per trip, and consuming one minute in making its entire up trip, or about two per round trip. The lower tank or water supply is on a level with the pump. The upper tank is 70 ft. above the pump, and in the piping to the upper tank are five elbows. For each elbow add 2 ft. to the elevation, or an approximate total elevation of 80 (ft.) × 120 (gals.) gives us 9,600 foot gallons. This amount would be required every two minutes if the elevator was in absolutely constant operation, or 4,800 foot gallons per minute × 8½ gives us 40,800 foot pounds. This we must at least double to allow for friction in pump, shafting, etc., making 81,600 foot pounds, or about 2½ h. p., say 3 required in the motor.

This class of elevator is confined almost entirely to passenger use; therefore, the service required of the motor is much more constant and the margin between the h. p. hours contracted for and the h. p. hours of actual service much smaller than in any other elevator use, excepting possibly the services in connection with pressure tank elevators in the more popular office buildings. In this case we have a maximum average use of 80; and instances, such as those of the hotels, small office buildings, etc., where the service will not exceed 60 of the contract h. p. hours. In order, however, that the electric light company shall derive the greatest benefit from this inconstant service, the installation and wiring should be the best, and only the most approved and economical apparatus employed.

The next application on our list, pressure tank pumps in connection with elevators, represents a somewhat smaller percentage of horse power hours of actual service in the motor as compared with the possible horse power hours than in the case of an open tank pump. In case of the pressure tank the water reserve is usually limited, and the motor, therefore, must be equal to the continuous operation of the elevator at maximum load. Taking this fact into consideration, and the circumstances of elevator use being about the same in this case as in the case of the open tank elevator, we have a greater ratio of difference between the possible or contract horse power hours in the motor and the horse power hours of actual service, the maximum average use being about 70 per cent. to 75 per cent., and the minimum as low as 35 per cent. to 40 per cent., depending, of course, on the character of the building in which the elevator is employed or the character of service. In calculating the size of motor required on an elevator of this description, a very convenient fact to remember is that every pound of pressure per square inch is equivalent to lifting water about 23 feet, or about 230 feet per 100 pounds pressure. By reducing the required pressure to a relative lift in feet, and knowing the amount of water required by the elevator per minute, the motor calculation becomes the same as in the case of the open tank elevator, the same allowance being made for friction, etc., as in the first case. The regulation of the motor in this case should be accomplished by the conditions of pressure in the pressure tank, as is the case with a steam pump employed in this service.

The next application of importance on the list is sewing machines. In the tests I have been able to make on this class of work I have obtained some singular results. One item of importance is the fact that the single thread machines, which are the lightest running, command the most power in operating. Paradoxical as this may seem, it is easily explained. As a rule this class of machine is used on light work, such as shirts, ladies' underwear, etc., and operated at a higher speed than any other class of machine. At equal speed the volts consumed on a single thread machine as compared with a shuttle machine is about as 2 to 3. In average commercial use, however, the positions are reversed, and the ratio of volts consumed in the single thread, as compared with the shuttle machine, is about as 5 to 3. To double the speed on a sewing machine requires about 2⅛ times the power. The difference in volts consumed on the different makes of sewing machines is so small that we may disregard it entirely, as well as the character of work done by the machine, for the heavier the work the slower the speed and more frequent and longer stops on the machine, thus keeping the average volts per operator about constant in all cases. This leaves the speed in stitches per minute at the sewing machine the factor from which we must calculate the power required in a sewing machine plant. To illustrate this, I will give you the record of two cases which are about the average. Case No. 1 is a shop in which are thirty sewing machines connected to a two horse power motor. At the time the tests were made there were but twenty operators at work, leaving ten idle machines, the entire shafting, however, being in operation. The class of goods manufactured in this shop is a cheap grade of cotton and wool pants, rather heavy goods to sew. A voltmeter across the terminals of the motor gave the following readings with a current of 9 amperes: Minimum, 90 volts; maximum, 148; average, 119; which gives us a minimum average per operator of 4·5 volts, and the maximum average of 7·4 volts, or a general average of 4·9 volts per operator. This motor was driving the shafting for 30 machines, and as the average operators employed the year round will not exceed 75 per cent. of the shop capacity, it will, I think, be entirely fair to estimate the average volts per machine rather than per operator, as the user of the motor has contracted for power sufficient to drive his entire plant. In this case, then, we have a minimum average of 3 volts per machine and a maximum of 4·9 volts, or a general average of say 4 volts per machine. A two horse motor of 83 per cent. efficiency with 9 amperes of current will require about 200 volts to develop two actual horse power. Two hundred volts, therefore, is what the electric light company contracts to deliver, while in reality they deliver only 129 volts, or 60 per cent., or a minimum average of 90 volts, or 45 per cent. of the power contracted for. These machines were making about 1,200 stitches per minute, an average of 4 volts per 100 stitches.

Case No. 2 is a shop in which are 32 machines running at about 1,200 stitches, each being supplied with an individual motor of ⅛ h. p. capacity, and the class of goods manufactured being men's summer clothing, such as white duck vests, flannel coats and vests, etc., the duck from which these vests are made being about as hard work on a sewing machine as can be found. In this shop were 24 operators at work. The maximum volts in this case was 116 and the minimum 40, or general average of but 78 volts, or about 2½ volts per machine with four more operators than in the first case, in which we had an average of 119 volts. This shop has been paying the electric light company $32 per month for more than a year, which is the price the same company charge for current for a 4 h. p. motor which approximates 400 volts, which the company contracts to deliver. This gives us a minimum average use of but 10 per cent. and a maximum of 29 per cent., with a general average of 19½ per cent. In other words, the company is saving in this shop the price of a ⅛ h. p. motor each month, besides making a profit on the volts actually delivered. On a contract for three years the electric light company would be money in pocket if they would present the customer with 30 small motors, charging him $1 per month per motor for current, rather than let him buy a 2 h. p. motor to operate the same machines, with the necessary shafting, at a charge of $18 per month for current. Taking this average in case No. 2 of 2½ volts per machine, from a 50 light machine we could run not less than 900 sewing machines, or about 18 to the arc lamp. At $1 per month per machine an income of $900 per month would be derived from a 50 light machine without any lamp expenses, such as carbons, repairs on lamps, globes, etc. On the average, in case No. 1 of 4 volts per machine, we could operate but about 562, say 600 machines. Divided up in shops of 30 machines and a 2 h. p. motor to each shop, we would have 20 two h. p motors. At a charge of $18 per month each we would have an earning capacity of but $360 per month from the same 50 light machine.

This is but one page from the thus far unwritten history of the much maligned small motor. Still the question is frequently asked: "Can we sell current for $1 per month for a small motor driving a sewing machine and make a profit?" As a matter of fact, 50 cents per month for small motors driving sewing machines yields a better profit to the company supplying the current than $10 per month per h. p. in large motors to drive the same machines, besides the immense advantage which the small motors possess of keeping the circuit in much better balance, the fluctuations due to the stopping and starting of large motors being at times a serious matter. One electric light company, making rather a specialty of these small machines, rents the motor and supplies the current for $1.25 per month per sewing machine, and reports that at this price the motor service pays them a better percentage of profit than their lamps. This company has some 200 small motors on the circuits.

A more striking illustration of the advantages to the electric light company in the subdivision of power into the smallest possible units it would be hard to find. There is a difference in efficiency of from 15 to 20 per cent, in these two sizes of motors, but this difference is fully lost to the large motor in driving the shafting, and the small motor still has the advantage of being out of circuit entirely when the machine it is driving is stopped. There is scarcely a manufacturing industry which does not possess its busy and dull seasons. This means that in no industry will over 75 per cent. of the machines or machinery employed be in average operation. The entire shafting in the shops must be kept in operation the entire year often for less than 50 per cent. of the machinery. Subdivide these same shops into as many small units as possible, and the current necessary to operate the shafting for this idle machinery will be saved, besides the saving from frequent stops while the machinery is in active use.

To return again to the list, the next two applications, picture frame manufacturers and moulding manufacturers, are very similar. Their busy seasons, as a rule, are in the spring and fall, and also follow closely any activity in house building. In the case of the larger manufacturers in this line a maximum average of 75 per cent. will possibly be reached, but probably never exceeded. In the case, however, of the picture dealer, who has a small shop in which he makes picture frames and mouldings to order, the actual service of the motor will fall as low as 25 per cent. or 30 per cent. of its contract hours; one case in our experience the actual service having reached this low average. A fair general average in this class of work would be about 60 per cent.

The next application, nickel and silver platers and buffers, are good contract customers as a rule; one case in our experience showing but an average use of 20 per cent. of the contract horse power hours. This, however, is probably an exceptional case, and as near as we can estimate on this class of work the actual motor service will not exceed in any case 60 per cent. of the contract hours; a fair average being probably 45 or 50 per cent.

The next two applications, printing presses on news and job work, are probably met with more frequently than any other. On exclusively news work, the instances where the motor is in service more than three or four hours is rare. It is, however, usual in news offices to find two or more job presses. If the newspaper printed happens to be a morning paper, the hours of news work are usually between 12 midnight and 4 o'clock in the morning, the job work being done through the day. I have in mind a case of this description. In the shop is one cylinder press and three job presses connected to a two horse power motor. This motor is on an incandescent circuit of 110 volts. To develop its rated power at 110 volts would require about sixteen amperes in the motor. An ampere motor in series with the motor while running off the morning paper with only the cylinder press in operation stood at 12 amperes. For three hours this load was practically constant, when it was thrown off entirely. This gave on the night service but thirty per cent. of the contract hours. This motor required five amperes to drive the shafting, and but eight amperes, or one horse power, to drive the three job presses with the cylinder press off. Here then is but a fifty per cent. use if the presses be used constantly; there are, however, many days when they are comparatively idle. Thirty to forty per cent., therefore, is a very safe estimate of the maximum use of this motor on the day circuit, or had the motor been a one horse power, which would have been sufficient to drive the job presses, the use would be sixty to eighty per cent. of the contract hours, probably not above 60 per cent. All printing offices will probably come within this range unless the motor be larger than is necessary to do the work.

Machine shops doing principally lathe work as a matter of course use a larger percentage of their contracted power than shops doing lathe and bench work with the same hands. In no case will the service of the motor exceed 65 per cent. or 70 per cent. of its contract use; for machine shops, like sewing machine shops, will never average over 75 per cent. of the shop capacity for operators the year round. The average, especially in the case of a shop doing much bench work, will fall as low as 40 per cent.

The driving of laundry machinery, which is our next application, usually proves a profitable contract, according to reports. This fact arises from the intermittent use of the machinery. The heaviest service on the motor will probably be found during the early part

* Read before the recent New York convention of the National Electric Light Association.

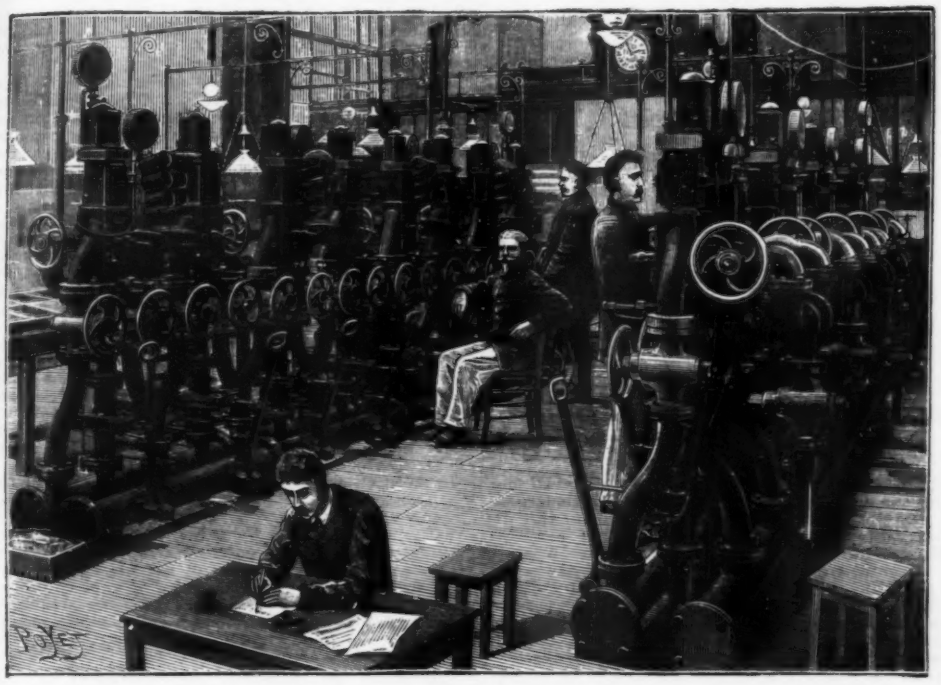
of each week, with a general falling off in work during the summer months, while the patrons of the laundry are away at the seashore or in the mountains. In this application, therefore, a 75 per cent. service would probably be an exception, with probably many instances where the service would fall below 50 per cent.

The next application, model and pattern makers, are small users of power, as their occupation requires a large proportion of hand work. Fifty per cent. service in the motor will be found a fair average maximum use, with instances as low as 20 or 25 per cent.

The next application, direct power or belt elevators, is another application frequently met. The average service in the motor is also much smaller than in any other elevator application. Let us suppose a case of the current out when the motor is not in use, the average use would drop to 20 or 25 per cent., instead of 37 per cent. In the case of a direct power passenger elevator, the use might possibly run up to 60 per cent., but this would be exceptional.

Coffee mills will average from 40 to 60 per cent. of their contract hours, manufacturing jewelers about the same, while retail jewelers will run as low as 25 per cent. Ice cream freezers will not average over 25 per cent., but as the contract season in this case is usually short, they should be rated at least a 50 per cent. basis, except, possibly, in cases where the customer pays the cost of installation and wiring, which is usual in these cases.

A dentist is one of the smallest of power users, so small, in fact, that if every one in the city were con-



THE CENTRAL TELEGRAPH OFFICE, PARIS—THE PNEUMATIC APPARATUS.

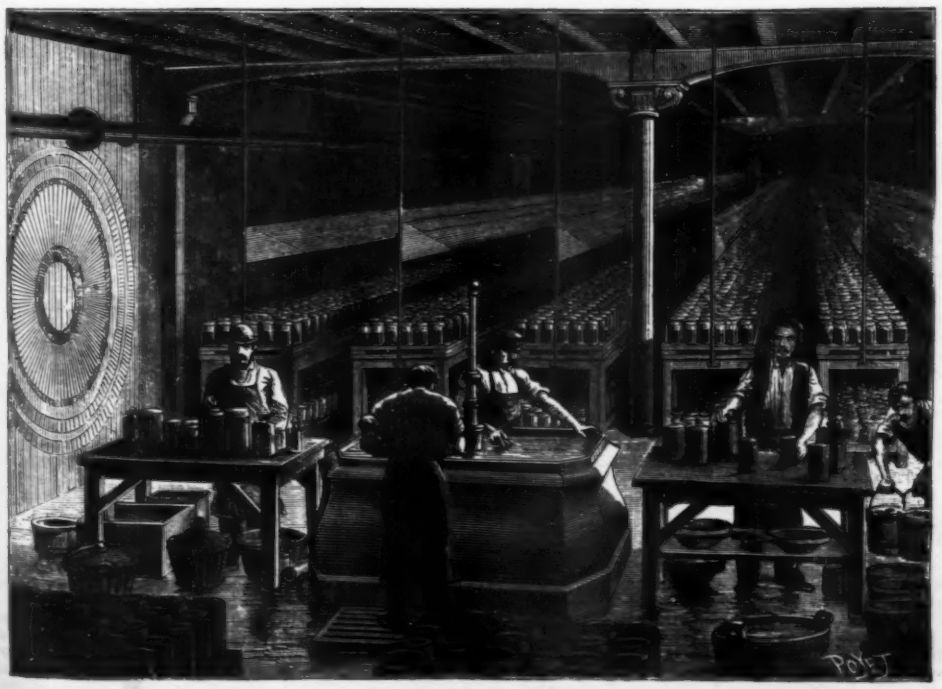
the familiar grip connected to the ordinary hand hoist with a lifting capacity of 2,000 pounds. In this case the motor is in use only going up, and the usual brake is used in coming down. Connected to this elevator in the loft of the building we have a 5 horse power motor wired to a cut-out on the ground floor. We will call the lift 45 feet and the time consumed per trip 1 minute. We will allow 60 full trips of the elevator at full load at 2,000 pounds per trip each day. This would approximate ten car loads of merchandise handled by the elevator, which is certainly above the average. This motor, we will say, is on a ten hour day circuit; its possible horse power hours, therefore, would be 5 horse power for ten hours, or 50 horse power hours per day. Sixty trips of one minute each gives us exactly one hour's service of the full 5 horse power or 5 horse power hours. To drive the shafting only while the elevator is coming down or idle would require about 150 volts, or 1½ horse power; and if this was in constant operation the balance of the day, nine hours, its total use on shafting would be 13½ horse power hours, which, added to the 5 horse power hours, gives us a grand total of 18½ horse power hours, or 37 per cent. of the contract hours. If, however, the user of the motor avails himself of the cut-out box and cuts nected with a circuit, the load from this cause would never be felt. We will, however, put them down at from 10 to 20 per cent.

The optician uses a motor to turn his grindstones, and its use in this case will average from 20 to 30 per cent.

The last application on the list, church organs, use only from 10 to 20 per cent. of the contract service.

These are, of course, but few of the very many appli cations of the electric motor, and if, as I trust, the possible subsequent discussion of this general plan may establish a basis for rating motor applications, not only will the object of this paper be obtained, but a question of considerable annoyance now existing between the motor man and the electric light and power company will be solved.

In conclusion, Mr. Chairman, I beg to suggest that the supply and rates of charge for electric power have become of sufficient importance to this Association to be represented by a permanent committee, whose duty it should be to obtain from the different members of the Association, as far as possible, their experience in the supply of power, in such manner and form as shall be deemed by the committee best suited to the wants of this Association.



THE CENTRAL TELEGRAPH OFFICE, PARIS—THE GREAT BATTERY OF 10,000 ELEMENTS.

[ENGINEERING.]

WAR SHIPS OF THE FUTURE.

IT is certainly by no means an insoluble problem in the present day to construct a ship possessing the required qualities of high speed, invulnerability to the attack of present and future torpedoes, unsinkable by guns, and provided with great offensive power and handiness, though the enormous cost of such colossal structures is a most powerful obstacle to their creation. No nation, however wealthy, could afford to construct its fleets of units, each one of which represents an immense expenditure, even though held superior to many others of inferior power, because the invulnerability and power acquired by this expenditure cannot guarantee the colossus against the dangers of disasters at sea, fire, explosions of boilers, and other possible catastrophes, nor against other still more potent agents of destruction which the future may have in store.

Being unable to obtain the necessary complete resistance to sinking when the endeavor is made to fulfill all the other requirements, the necessity will become more and more obvious, as time goes on, of obtaining that quality by sacrificing some other conspicuous characteristic of the ship. Among all the factors which now constitute the military power of a ship, that of velocity is without doubt the most prized, and also the one which has been the chief cause of the increase of cost, as well as that which more especially precludes the adoption of a form and construction of the hull which would be better able to resist the offensive development of sub-aqueous weapons.

It is the velocity therefore which will have to be sacrificed to the advance of the new weapons. This sacrifice will be no doubt strenuously opposed, as speed is always dear to the sailor, accustomed to associate this quality as a leading feature in a good design of ship, but the supreme law of the safety of the ship will force its adoption. Between the alternative of accepting the perpetual danger of being sent to the bottom at any moment or of giving up an excess of speed, no hesitation is possible in adopting this latter solution, however painful the decision may be. This modification in the qualities of a battle ship will naturally not be by itself a solution of the problem, and it will have to be followed by others, but as the most radical, and perhaps the most contested, its consequences deserve examination.

For battle ships a sensible excess of speed over an adversary was a distinct advantage, when the guns were ranged along the broadside, because in that case the swifter ship could assume a position from which she could attack the other without being herself attacked. It was also an advantage when the attack by ramming was thought likely to be adopted; but in the present day the system of rotating platforms, which defends equally nearly all the points of the horizon, has caused this advantage to disappear. The modern systems of construction and torpedoes, having led to an abandonment of the attack by ramming, have also contributed to this result. High speed was retained as a principal defense against the attack of torpedoes, and this was in part justified, when the velocity of the torpedoes was only about half that of the ship. At present both the torpedo and the torpedo boat possess a speed considerably greater than that of the battle ship, and in consequence speed can no longer be considered as an arm of defense for these last. A superiority of speed is not of very great advantage in the phases of a combat, because the pauses arising from the necessity of maneuvering interfere with its advantage being realized. The superiority of speed, it is true, confers the power of choice in accepting or refusing an action, but the occasions are rare and exceptional when a commander would be justified in making use of the latter prerogative.

A reasonable diminution in speed produces no deleterious consequences in case of an artillery combat, when it is sacrificed to obtain immunity against torpedoes. Between a Duilio or an Italia, possessing a speed of fifteen knots, but liable to be sunk by the explosion of a torpedo, and a ship of nearly equal power and of less velocity, but invulnerable to the attack of a dozen torpedoes, the choice cannot be doubtful. For that reason sooner or later large battle ships will have to accept a sacrifice of speed in order to obtain immunity to torpedo attack.

Without doubt many will dispute these conclusions, pointing out that inferior speed leads to impotence, because the quicker ship can always withdraw from the attack of the slower, and that the latter cannot escape ramming by the former. These critics forget, however, that speed given to a structure which can be easily sent to the bottom is ephemeral, and that an effective protection against torpedo attack will in a large measure be a defense also against ramming. Experience, however, will, in the end, dispose of these and other objections, as it will demonstrate that superiority of speed, if unaccompanied with invulnerability, is no secure guarantee of being able to take flight, because the high power and accuracy at great distances of the guns of the future will easily clip the wings of the fugitive. If the quicker vessel is reduced to flight on the appearance of the slower one, that signifies that the latter will be master of the field, remaining where it chooses, and where necessary to attain its object, for it cannot be contested that a ship should always have some fixed purpose to fulfill, and not alone that of flight. The slow ship, invulnerable to torpedoes, can always force her swift, though vulnerable, rival to quit any particular spot, while the same compulsion can never be exercised upon her, whether she maneuvers furnished with nets or without, and that for reasons which are self-evident.

To sum up, the renunciation of an excess of speed in order to obtain security against torpedoes is the means most adapted for clearly defining the role of such battle-ship, and for rendering her more efficacious in the field of action for which she is destined. This difference of speed between the more powerful vessels and those of less size will be accepted in future as the lesser speed of the line-of-battle ship in presence of a frigate, and of the frigate as compared with the corvette, was accepted in former days. Every ship must have some one factor largely developed at the expense of some other less essential for her particular duties. Future fleets must have their Uhlans, their heavy cavalry, and their light artillery, but their real fighting strength will consist of large vessels of reduced

speed but unsinkable, and against these the assaults of an enemy who has preferred speed to unsinkability will prove fruitless.

The sacrifice of a portion of the speed will be principally due to the necessity of providing the hull with projecting coffers or plating with free circulation of the water, as a protection against torpedoes; their distance from the hull being determined by the explosive charge of the torpedo. Without discussing their details or form Admiral Albini holds that this mode of protection, giving free access to water, is the only one on which reliance can be placed. It should project at least 13 ft. from the hull.

A reduction in the speed will not suffice by itself to furnish means of giving adequate protection to the hull, and a considerable diminution in the armor now applied to ships will, he considers, have to be effected. With the existing power of guns, which is susceptible of being largely increased, the practical superiority of the gun over armor may henceforth be assumed as incontestable.

Guns are even now in existence which develop an energy of 70,000 foot tons and can perforate over 30 in. of the best armor. It is useless to look for adequate protection by increasing the thickness of armor plates. The wisest course is to make use of a large portion of the excessive weight of armor in a manner which will really contribute to the safety of the vessel.

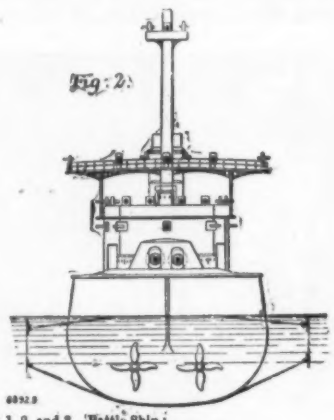
This reduction will also have its strenuous opponents; as a system of defense which has entailed much time, study, and cost will not be readily abandoned. The change will consequently be gradual, but in the end the imperious necessity of making the ship unsinkable will force its acceptance.

It is difficult to fix the limit to which this reduction in armor will descend, as it will depend in great measure on the various duties assigned to the vessels and on the development of the smaller classes of guns. Admiral Albini holds that for all parts of the ship above the water line which are not intended to contribute to the floating power, and which must be protected by vertical plating, the thickness of the armor should be determined by the penetrating power capable of being developed in quick-fire guns, or in light guns of such moderate weight that large numbers can be carried. As it is impossible to associate high penetrating power with rapid fire without a considerable increase of weight and space, he considers the 6 in. gun as about the limit to which this system can be advantageously applied.

Good armor, 12 in. thick, is impenetrable to all the class of quick-fire weapons, and this thickness for vertical protection should not be exceeded. A ship, secure in this manner against the quick-fire shell attack, realizes that prudent measure of defense which will justify her undertaking a combat, accepting the risk of some fortunate shot from the big guns paralyzing a portion of her armament. Ships have been exposed to this risk at every period, as one of the hard necessities of warfare. Moreover, it is a danger which may be accepted all the more readily if its acceptance conduces to insure floating power in presence of torpedo attack, for even with all the guns disabled the ship still floats and can maneuver, steer, and attempt a ram attack, whereas with a large breach in her hull she will sink, notwithstanding that her guns are uninjured.

The experience of late naval actions tends to confirm that gained in the old wars, to the effect that even a heavy and sustained fire produces comparatively small results as far as disabling the guns and their mechanism is concerned. It was the repeated destruction of the gunners of the Huascar which brought about her surrender. It is therefore desirable to make the guns of the future automatic as much as possible. By reducing the number of men engaged, and substituting machinery, the effect of fire will be less injurious.

The abandonment of excessive thicknesses of armor, because incapable of withstanding the power of very large guns, will lead naturally to a disposition to give up the big guns themselves, as beyond the requirements of the case, but there are obvious reasons against this proceeding. Where great power is available it can be employed as needed. If one motive is removed, another easily appears. The large gun, as it is able to respond to various requirements, will be retained for a considerable period, though perhaps applied in smaller numbers, as a preventive to a fresh expansion of armor. Under many circumstances one hit from a big gun is more efficacious than a salvo of smaller projectiles, and for high effect at long range no other gun can be substituted, as the reduction in thickness of the armor carried by ships will not bring about a similar reduction in land defenses, where weight is of no consideration.



Figs. 1, 2, and 3. Battle Ship:
Armament 4 100-ton guns;
18 6-in. guns;
28 rapid-fire guns
50 machine guns.

With the development of new explosives, shell fire against the unarmored parts of a ship will be largely used, and the big gun possesses great power in this direction; the calibers of guns will probably be increased to gain greater effect in this nature of fire. Against the horizontal armor of the future the large gun is the only one which is likely to inflict serious injury, particularly at short range and with plunging fire. On the whole, the abandonment of the big gun would be a very ill-advised step.

The reduction in vertical armor for the protection of the guns will enable the horizontal armor to be largely increased. Though hotly disputed, Admiral Albini thinks there can be little question as to the superiority of horizontal over vertical protection.

If the chief object which armor is intended to subserve is that of rendering a ship unsinkable and of maintaining her motive power in full efficiency, both now and also in the future, this result can be attained by horizontal armor, while impossible with vertical armor, for the simple reason that one system is penetrable by artillery fire and the other is not; at least within the limits of a reasonable thickness of plating. More than 32 in. of armor is necessary to resist the present guns, and the racking effect of these huge projectiles is such that a very large addition will probably have to be made to the supporting structures in order to prevent the whole side being forced in. The total weight becomes so great as to be inadmissible in practice.

If the vertical armor is perforated, the life of the ship is absolutely menaced, not only because the engines, boilers, magazines, and other vital organs are exposed, but from the large openings for ingress of water which will be formed, hazarding the sinking of the ship. A single hit from the 100 ton gun may produce this sudden catastrophe. Nor can it be hoped that the disaster can be avoided by relying on the small chance of a projectile hitting the water line, such precision being in fact unnecessary. Any one who has witnessed firing trials of the 100 ton gun against armor must be convinced that even striking a yard above the water line, the injury will extend to a considerable depth below it, for the damage caused is not of the nature of a round hole, but of a wide breach. With horizontal armor, on the other hand, this danger does not exist, as good 4 in. steel plating placed 45 in. below the water line cannot be pierced under the actual conditions of naval warfare, as it is not possible to hit it so as to pierce it. Up to 2,500 yards there is complete immunity to shot, as their path is practically tangential to the surface of the armor. At 2,500 yards the angle of impact would be 5 deg.—insufficient for perforating. Only at 4,000 yards, when the angle of descent becomes 15 deg., is any danger to be anticipated, but at this distance the attempt to fire at the water line is out of question, the chance of hitting being 1 in 1,000.

If, in addition, the armor is surmounted with cells 45 in. high, filled with gas coke, it will be able to resist even the fire of the future giant guns, not only on account of the united resistance of the two materials to the energy of the shot, but also on account of the deflecting power which the coke will oppose to the projectile at the angles of descent under which they will strike its surface.

Admiral Albini claims that coke is the best substance for this purpose, as it can be used as a combustible if needed, is of small cost, is not liable to spontaneous combustion when packed in inclosed spaces, has only one-fourth the weight of coal, and he has proved by experiment that it is more resisting than coal to the blow of the shot, and tends more to deflect it.

Notwithstanding these advantages, it will be impossible to stop the rupture of the underlying armor, if a highly developed curve is given to it, instead of being placed flat. The curved protecting deck gives more space for the engines and diminishes the quantity of water which can flow into the cellular spaces, but is easily perforated, and, as regards keeping the vessel afloat, inferior to the flat deck.

In addition to maintaining the power of floating, horizontal protection has the following advantages: Greater security against a ramming blow; the ship is equally protected throughout her whole length; gives greater freedom to the mode of arranging the armor-protected guns; is a measure of defense against high angle fire from land guns; economy in cost of protection; and lastly, less probability of being struck, as the very flat trajectory of modern guns makes it easy to hit a vertical target, while a very small error suffices to miss a horizontal one.

Objections will be raised to the advantages here attributed to horizontal armor, that if vertical plating is no guarantee against the few powerful guns now existing, it will do better against shells filled with high explosives from smaller guns, which will break up against the armor before penetrating, whereas in the other case they can freely penetrate and develop their full explosive effect.

In reply, Admiral Albini points to the increasing numbers of very heavy guns now carried. The assertion, also, that vertical armor is proof against shell is not entirely the case. With the steel shells now in use armor of considerable thickness can be pierced even by second-class guns, so that, unless recourse be had to complete protection by means of very thick armor, which is inconsistent with the design of a ship of moderate size, all attempts to adopt armor as a defense against modern shells is illusory.

Even if it be admitted that vertical armor is a defense against the shells of second and third class guns, its inferiority of protection as compared with horizontal armor will always be evident, as in the end we are compelled to conclude that a vessel protected with vertical armor will be defended against

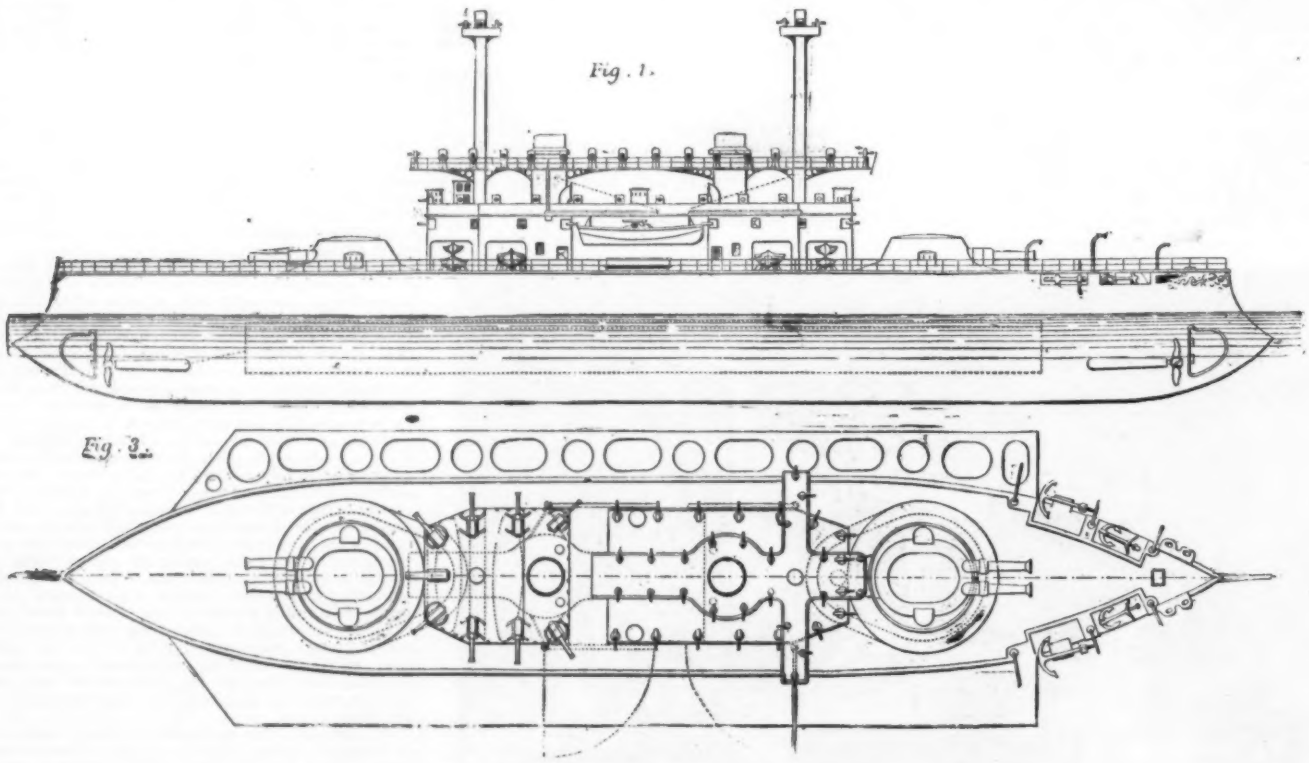


Fig. 1.

Fig. 3.

WAR SHIPS OF THE FUTURE.

the fire of small shells, but is exposed to being sunk by big guns, while horizontal armor is a complete protection against both modes of attack. In fact, if a shell from a 100 ton gun strikes a little above the water line, it will in most cases explode in the spaces above the cellular structures without damaging the vital organs of the ship, but if it explodes within the cells, experiment has shown that the effect will be limited to destroying the covering plating of the cells without breaking in the underlying armor. Even if many shot of this nature should strike at different points of the horizontal zone, they would have no influence on the stability of the ship, nor on the proper functioning of the organs of offense, as the cellular belt contains no vital organs, and should be considered solely as a zone of support to the structure above it, and in consequence may be frequently hit without being reduced to a condition of not being able to fulfill its function, and being also full of coke, may be pierced in a hundred places without admitting a sufficient quantity of water to do any harm.

In view of the superior powers of resistance to the attack of large and small guns which horizontal armor has been shown to possess, Admiral Albini concludes that it is the form of protection best adapted for use in the future. Another modification which will prove both necessary and advantageous will be that of giving greater maneuvering power and greater protection to the propellers against the injuries of torpedoes. The first quality is rendered indispensable in order to remedy in part the defects arising from a reduction in the speed, the other is suggested by the necessity of diminishing the danger of the ships being disabled by numerous torpedo attacks and of attempts to injure the rudder and propellers. This necessity becomes evident when we consider that the advantages resulting from the prudent principle already carried out for some time of duplicating the most important organs of the ship lose half their value unless the principle is applied also to the propellers and rudder.

A ship which is disabled in her means of propulsion is irretrievably doomed. That this danger is not remote is proved by the fact that the results of firing torpedoes against a ship in motion show that the tendency of errors in aim is to make the torpedoes pass near the stern of the ship, and if they explode there, there can be no doubt that the screws and the rudder will be disabled, as it is very difficult to properly protect this portion of the ship. Admiral Albini considers that the best means of avoiding this danger is to make both ends of the ship exactly alike, with screws and a rudder at each end, which can be used either for increasing the power of maneuvering or as a substitute when one extremity is disabled.

In conclusion, he holds that the battle ship, far from disappearing from the high seas, will become more powerful than ever, subject to the following modifications:

Displacement, approximately the same as that of the latest battle ships, with symmetrical ends, both provided with rudders and screws.

Great beam, with defense against torpedoes by means of projecting plating, leaving a free passage to the water.

The hull unsinkable by the fire of heavy artillery by means of horizontal steel armor 4 in. thick, placed 45 in. below the water line, and covered by a layer of coke of equal depth.

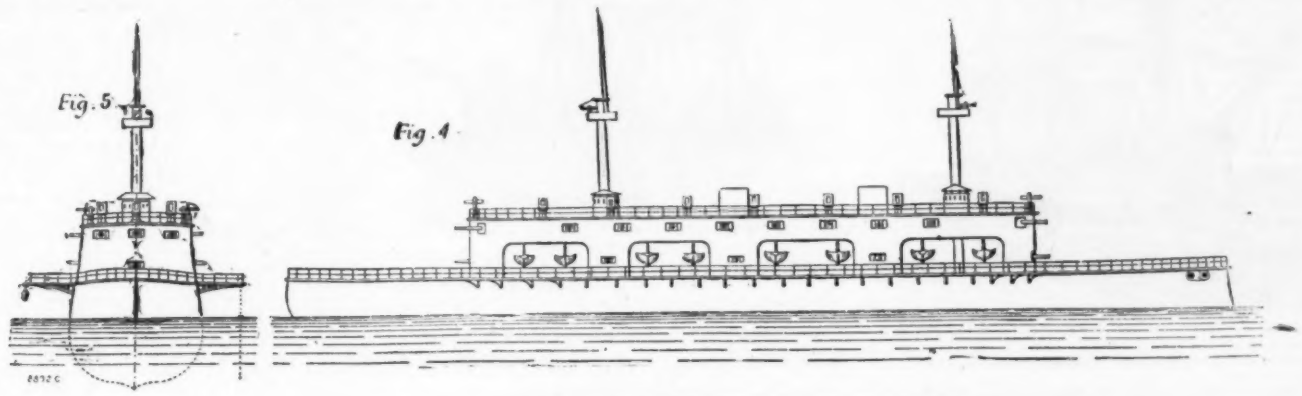
The armament to consist of four guns of great power placed in barbettes, two at the bow and two at the stern, protected by 13 inches of armor at an angle of 25 degrees, with an external covering of coke a yard thick.

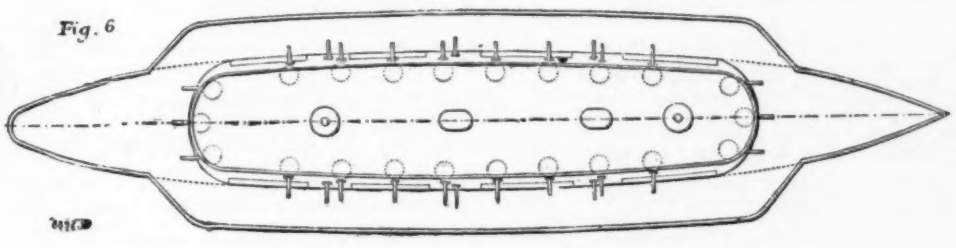
The central battery to be in two tiers placed high above the water line, and to consist of light artillery made automatic as much as possible; not less than twenty 6 in. and forty rapid-fire guns to be carried.

merchant ships. As in this case there will be no armor to penetrate, this excess of power is best attained by the possession of a very large number of guns, ranged perhaps in two tiers, the lower composed of at least twelve guns not exceeding 5 or 6 tons in weight, but of large caliber, not less than 10 in., specially intended to fire large shells filled with a high explosive; the upper tier to consist of at least twenty rapid-fire guns capable of being used on either broadside. They, as a natural accompaniment, possess high speed and an armored deck below the water line. In these ships the part above the water will probably be constructed so as to be able to receive a permanent arrangement of nets as a defense against torpedoes. Figs. 4 to 8 illustrate two types which he suggests.

Smaller vessels of the same type will also be required. They will differ but little from the others except that they will carry fewer guns.

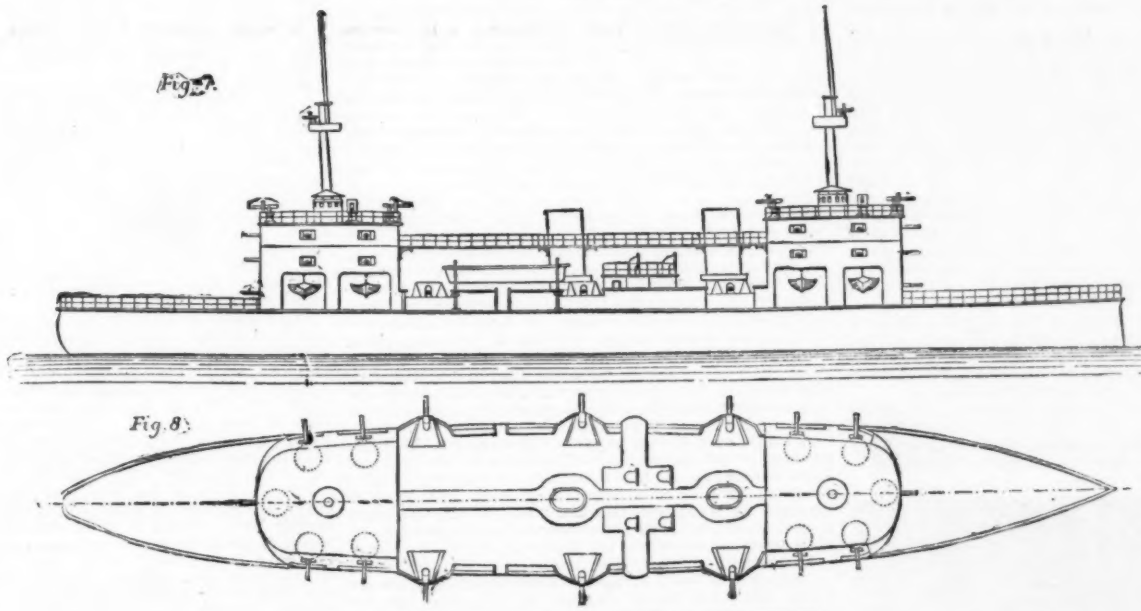
The dispatch vessel or naval scout will in the future hold a very important position among the smaller class of ships. Many persons think that in the dispatch vessel everything should be sacrificed to attaining a very high speed, and consequently that she should be entirely without armament, since every pound of weight devoted to this interferes with her possessing





Figs. 4, 5, and 6. Cruiser with automatic gun-mountings and a permanent system of nets:
Armament 30 6-in. guns.
20 57 mm. rapid-fire guns.
Total 50 guns.

Figs. 7 and 8. Cruiser with automatic gun-mountings:
Armament 28 6-in. guns.
12 57 mm. rapid-fire guns
Total 40 guns.



WAR SHIPS OF THE FUTURE.

Speed, under six hours' continuous trial, to be about twelve knots.

Admiral Albini's design for a battle ship is shown by Figs. 1 to 3.

Turning to details, Admiral Albini dwells upon the necessity of providing adequate protection for the commander of the ship, which he thinks can best be realized by a number of positions which will conceal the actual place of the captain from the enemy. For second-class battle ships he suggests a vessel of about 7,000 tons displacement, and mean speed twenty knots, protected by a horizontal deck 2 in. thick, placed about 5 ft. below the water line, with coal above in cellular spaces. She should carry two 10 in. guns, one at each end, and forty rapid-fire guns on various superstructures, placed at a great height above the sea, to which he would add the novel disposition of six mortars able to throw to fifty yards distance a charge of explosive gelatine 1,000 lb. in weight.

He finds greater difficulty in determining the form and dimensions of the smaller classes of vessels. He points out that any endeavor to make these vessels capable of engaging larger and more formidable types can only result in failure, and therefore that their offensive powers should be strictly limited to the performance of the duties for which they are intended.

This duty he holds to be principally that of being able to encounter with a great excess of power armed that fractional excess of speed which will constitute her superiority over her adversary. She should never stop to accept an action, as that would retard her mission, which is to gain and give information. Admiral Albini does not support this view, holding that in practice it would be very difficult to utilize these minute differences, whose effect within the limits of the weight of the armament of such a vessel can be neutralized by the circumstances of the weather, the heel of the ship under the effect of the wind, the length of time she has been under steam, and other very slight causes. To be without any armament would rather impede than facilitate the execution of her duties. If an unarmed scout meets an armed one, the latter would prevent her flying by engaging her, and the small superiority of speed would not enable her to escape the projectiles of her adversary. An armament for these vessels of two 36-pounder guns at the bow and two at the stern, mounted together on revolving platforms, would, he considers, fulfill all requirements.—*Engineering.*

GERMAN engravers and watchmakers get a hardness on steel tools almost equal to that of the diamond—it is said—by plunging them when white-hot into sealing wax, repeating the process until the steel is too cold to enter the wax, and then just touching them with oil of turpentine.

THE SOLOMIAC TORPEDO NET.

THE unexpected appearance of the torpedo boats in fleets of war has not failed to deeply trouble the officers whose duty it is to lead the latter to battle. But, just as they have protected their wooden vessels by armor plating them against the ever-increasing power of artillery, just so science, always on the alert, has furnished them the means of protecting themselves against the tentatives of the torpedo. This idea they owe to Mr. Bullivant, an Englishman. Mr. Bullivant's system consists of a metallic net with circular meshes suspended here and there from wooden or iron supports, called booms, movable around a hinge, and, when at rest, capable of turning down along the sides of the ship, while the net rolls up.

The maneuvering is done by hand, and takes about fifteen minutes. The booms, turning around their point of attachment, place themselves at right angles with the sides of the ship, and are held in this position by ropes, while the net, unrolling, falls plumb at six

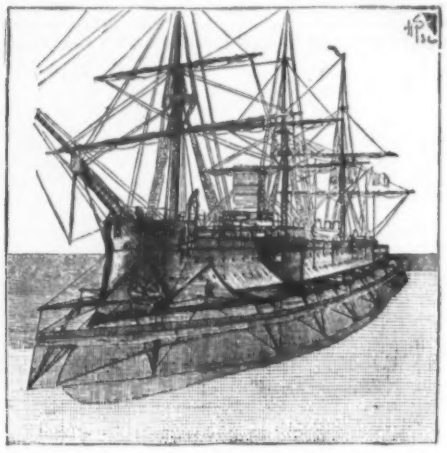


FIG. 1.—SOLOMIAC'S TORPEDO NET.

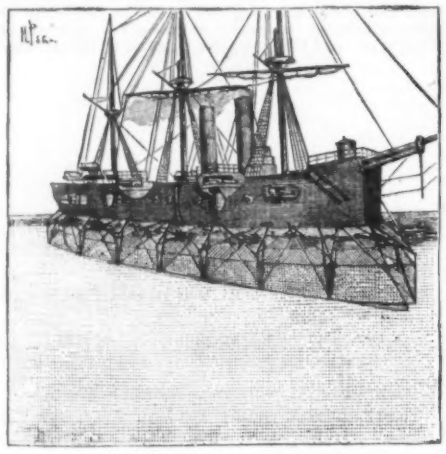


FIG. 2.—SOLOMIAC'S TORPEDO NET.

yards from the hull, if the ship is stationary. In sailing, also, the Bullivant nets can be used at speeds of less than four knots per hour, but their efficacy then rapidly decreases. Suspended simply from the booms, they are drawn toward the stern, are brought to the surface, expose the hull, and form around the vessel a confused mass which weights it and risks engaging with the screw.

This mode of protection presents another inconvenience, and that is the relative slowness with which it is put in place, and which makes it necessary to perform the operation in advance, in provision of future attacks, no recourse to it being possible if the ship is unexpectedly assailed.

These defects of the Bullivant process, which, along with the slowness that it gives the ship, threaten to make the use of it discontinued, have attracted the attention of a Frenchman, Mr. Solomiac, who has studied the problem, and who seems to us to have very well solved it by singularly improving the English invention.

In his system, the booms, when not in use, are placed within the vessel. They slide between two guides, thus permitting of their being pushed out to their proper position by a simple movement forward through special portholes, or of being drawn back into the interior by a contrary motion. They form a horizontal plane at about a yard and a half above the float water line, and are arranged parallel with one another at the central portion of the vessel, but spread out like a fan at the extremities.

The net completely envelops the ship at a distance of 23 ft., when in position. When not in use it lies flat against the planking. The meshes are rectangular, and this permits of the net being folded, after the manner of Venetian blinds, with very great rapidity.

The net is not only held above by booms, but below also by metallic pieces called stretchers, which unfold and fold up like the booms under which they lie when at rest. The net, thus fixed by its edges, cannot fall to

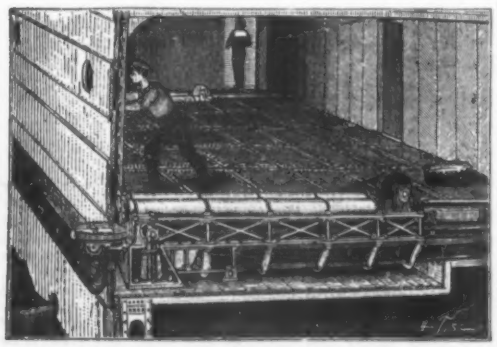


FIG. 3.—COMPRESSED AIR APPARATUS.

the rear when the ship is in motion, as in the Bullivant system, and remains like a curtain, even should the speed be 10 or 12 knots.

The stretcher, the booms, the guides of the latter, and the parts producing motion form a single apparatus capable of pivoting around journals placed near the planking, thus permitting of immersing the net in an instant to six feet greater depth, should such a maneuver become necessary, and of thus protecting a region situated much deeper below the float water line without an increase of the height of the metallic curtain.

Motion is produced by compressed air furnished by a reservoir of small capacity. As in the well-known Westinghouse brake, this air is distributed between the various apparatus by a system of tubing, and acts upon the faces of a piston whose to and fro motion is transmitted to the boom and stretcher. As in the brake just mentioned, the maneuver of the whole affair is concentrated in the hands of one man, who, by the simple play of a lever, in one direction or the other, can put the net into the sea or raise it, in a space of time that the inventor thinks should not exceed 20 seconds for each of the motions.

Finally, let us add that the apparatus are installed in the batteries after the manner of artillery pieces, and that the compressed air tubing, which is of small diameter, is placed in the vessel just as the water and gas pipes are in our houses.

Upon the whole, the Solomiac process is greatly superior to that of Bullivant. While it takes a quarter of an hour to put the latter's nets in position, with the help of part of the crew, and while it is possible to use them only when at anchor, those of the new system, without requiring any *personnel*, and with a rapidity truly remarkable, assume the maximum of possible protection by a maintenance of the rigidity of the whole, whether the ship be sailing or at anchor.—*La Nature.*

[Continued from SUPPLEMENT, No. 669, page 10684.]

COVERED RESERVOIRS.*

By CHAS. H. SWAN, Civil and Sanitary Engineer, Boston, Mass.

METHODS OF CONSTRUCTION.

A COVERED reservoir does not usually present any serious difficulty to the engineer. It should be built of materials that are durable and which are not liable to injure the quality of the water. Iron has been used for pillars, girders, or covering; but its use is to be avoided on account of its liability to corrosion. Small reservoirs may be covered with ordinary roofs or sheds; but these do not usually afford a sufficient protection against the heat. The best and most usual covering is of masonry or brickwork covered with a thin coating of asphalt to prevent the percolation of surface drainage, and by a layer of earth. The numerous covered reservoirs near London are mostly built in this way. It is usual to provide numerous ventilators.

The shape and constructive details are greatly dependent upon local conditions. The following types are common: 1. A circular reservoir covered with a flat dome. 2. A circular reservoir of larger size divided by circular walls into several annular compartments, each of which is arched. 3. A rectangular reservoir divided longitudinally by straight walls into several compartments, each of which is arched. 4. A reservoir covered by groined arches supported upon masonry piers. There are also variations of these types made by using iron. It is very common to make openings in the division walls, thereby uniting two or more compartments. In some instances these openings are so extensive that the wall becomes virtually a series of piers.

It would extend this paper to unwarrantable limits to attempt a description of the details of reservoirs of these various types, but it will be interesting to give descriptions of two covered reservoirs recently constructed at Mulhouse, Germany, and of the two-story reservoirs of Paris, which consist of one covered reservoir superimposed upon another.

MULHOUSE.—This city is situated between the source of supply and the hill upon which the reservoirs are built; the water being pumped directly into the distribution pipes.† Its topography requires a high service as well as a low service system. The low service reservoir is so placed that its bottom is 35·85 meters (117·6 ft.) and its maximum water level is 39·65 meters (130 ft.) above the mean level of the streets. The high service reservoir situated 50·88 meters (167 ft.) above the low service reservoir, furnishes water to a limited suburban district containing a population of only 130 persons; about one-third of the area of the high service district being cultivated as gardens. The upper reservoir is supplied by pumps from the lower reservoir. It has a capacity of 1,800 cubic meters (475,000 gal.), which is the estimated maximum consumption for one day.

The low service reservoir has a capacity of 10,000 cubic meters (2,640,000 gal.), which is about two-thirds of the maximum daily consumption. It is excavated in the earth, arched over and covered with earth. It is formed of two perfectly similar compartments, each being 38·6 meters (126·6 ft.) long and 35·2 meters (115·4 ft.) wide. The walls on the sides which receive the thrust of the arches have a thickness at the base of 2·5 meters (8·2 ft.) reduced by steps to 1·35 meters (4·4 ft.) at the top. The walls on the other sides have a mean thickness of 1·15 meters (3·9 ft.). The wall separating the two compartments is 2 meters (6·6 ft.) thick at the base and 1·5 meters (4·9 ft.) at the top.

The covering arches are cylindrical, and are built of brick and cement in circular segments of 5 meters (16·4 ft.) span and 1·2 meters (3·9 ft.) rise. They are 35 cm. (14 in.) thick at the springs and 23 cm. (9 in.) at the key. The intermediate walls which support the arches are themselves pierced with arched openings which allow communication between the different bays. The pillars which are left between these openings are of brick and cement masonry. The skewbacks are all of cut stone. The exterior walls are of rubble masonry laid in hydraulic lime and lined with brickwork. The bottom is formed of a bed of concrete of hydraulic lime 35 cm. (14 in.) to 85 cm. (33½ in.) in thickness, covered with a course of bricks laid on edge in cement. The faces of the walls and pillars, the bottom of the reservoir and the intrados of the arches are covered with a smooth plaster of Portland cement 2 cm. (1 in.) in thickness, all the angles being rounded. The bottom has a grade of 0 002 toward the drainage openings. The extrados has received a covering of cement 3 cm. (1¼ in.) in thickness and has been covered with one meter (3·3 ft.) of earth. Drainage pipes are laid in the hollows of the arches to lead off the water of the soil. The walls on two sides are covered externally with a sloping embankment and turfed. The earth covering the top of the reservoir is cultivated as a garden, and is used as a public promenade. The interior of the reservoir is aerated by 27 ventilators emerging from the soil, and covered with caps of galvanized sheet iron, so arranged that nothing can be put in from the outside.

The influent pipe, which is also the effluent pipe, divides into two on reaching the reservoir, and each branch runs to the middle of one of the compartments. This arrangement is to facilitate the circulation of the water in the reservoir, whether it is flowing in or flowing out. A pipe 50 cm. (20 in.) in diameter, with a valve, passes through the division wall and permits a communication between the two compartments when desired. The depth of water is 3·8 meters (12·5 ft.). There is an overflow pipe and a drainage pipe in each of the two compartments. These pipes unite in a single one of 25 cm. (10 in.) diameter, outside the reservoir, discharging into a sewer, after passing a trap which prevents any emanations from the sewer from entering the reservoir.

All the pipes issuing from the reservoir pass through a chamber, in which are the valves. The facade of the structure forming this chamber is an Ionic portico in white stone, surmounted by a balustrade at the level of the top of the reservoir. The interior of the reservoir is entered by means of two circular iron stairs 1·4 meters (4·6 ft.) in diameter. To reach the top of the reservoir, in coming from the city, there is a stone staircase of several flights built in the slope of the embankment.

The high service reservoir is also excavated in the earth and covered with a meter of soil. It is in two compartments of 16 meters (52·5 ft.) by 17·53 meters (57·5 ft.) each, which are divided into 4 bays 4 meters (13·1 ft.) wide by means of walls of brick and cement 50 cm. (20 in.) thick. These walls have openings 4 meters (13·1 ft.) wide alternately at their extremities, so that the water, being led to the side opposite that at which it will flow out, has to traverse all the bays before reaching the orifice of exit. Stagnation of the water is thus prevented. This precaution is necessary in a reservoir of this kind, where the quantity of water to be supplied is very small, and even nothing during several consecutive days. The least work of the pumps thus sets in motion all the water contained in the reservoir.

The walls forming the sides have a thickness of 2·50 (8·2 ft.) to 1·75 (5·7 ft.) meters, those of the ends 1·15 meters (3·8 ft.) The arches supported by the intermediate walls and by the longitudinal walls have a span of 4 meters (13·1 ft.), 75 cm. (30 in.) rise, 37 cm. (14½ in.) thickness at the springs and 23 cm. (9 in.) at the keys. They are in brick and cement. The bottom is formed of 30 cm. (1 ft.) of concrete and 15 cm. (6 in.) of brick on edge. The interior linings and the ventilators are like those of the lower reservoir. The division wall across the middle of the reservoir is 1·5 (4·9 ft.) meters thick throughout its entire height. The maximum depth of water is 3·5 meters (11·5 ft.).

The influent pipe, after having passed the gate chamber, crosses all the bays of the interior and ends at the opposite longitudinal wall, where it turns upward by an elbow to the high water level. The effluent pipe is at the level of the bottom of the reservoir, but a pit 45 cm. (18 in.) deep is constructed at its inlet in order that it may not draw out any deposits which might have formed on the bottom of the reservoir. The four overflow and drainage pipes unite in a single one of 15 cm. (6 in.) diameter, which discharges into a rivulet.

PARIS.—Among the most notable, are the two-story covered reservoirs at Paris. This city derives its water supply from several distinct sources; from the river water of the Seine and the Marne; from the Canal de l'Ourcq; from artesian wells; and from springs. The waters from these different sources vary much in quality; that from artesian wells and springs being the purest. Spring water is brought by the aqueducts of Arcueil and of Belleville, but mainly by the new aqueducts from the upper waters of the Dhuis and the Vanne. The former supplies reservoirs at Menilmontant and Belleville in the easterly part of Paris; the latter supplies the reservoir at Montrouge in the southern part of Paris.

Reservoir of Menilmontant.—This reservoir receives, in two separate parts, the water from the Dhuis and the water from the Marne.* The capacity of the reservoir receiving the water from the Dhuis was fixed at 2·5 times the daily discharge of the aqueduct, or at about 100,000 cubic meters (26,400,000 gals.). It was not easy to find a suitable location for so large a structure at Paris. The high land on the right bank of the Seine is underlain with formations of gypsum, and this material has been so extensively quarried that nearly all the land not built upon is wanting in solidity. After a long search, an undisturbed site was found at Menilmontant, but consisting of the worst material, the green clay of Montmartre. Solid foundations were reached at a depth of 6 or 7 meters (20 to 23 ft.) In order not to be obliged to purchase a separate site for the reservoir to receive the water from the Marne, it was decided to establish this latter in the spaces between the long pillars forming the foundation of the reservoir for the water from the Dhuis, by excavating the clay.

The reservoir of Menilmontant consists consequently of two stories, each of which is divided into two com-

* From the Journal of the New England Water Works Association, Sept., 1888.

† Bulletin de la Societe Industrielle de Mulhouse. Nov., 1887.

* Belgrand. Les travaux souterrains de Paris. V. 4.

partments. The two lower compartments, of a capacity of 28,500 cubic meters (7,500,000 gals.), receive the water from the Marne, raised by the pumps at Saint-Maur. Their overflow is at the elevation, 100 meters (328 ft.) The two upper compartments, of a capacity of 100,000 cubic meters (26,400,000 gals.), receive the water from the Dhuis and from the spring of Saint-Maur. Their overflow is at the elevation 108 meters (354·3 ft.) The useful area of the reservoir is 2 hektares (5 acres). Its cost was about 28 francs per cubic meter of useful capacity. It was begun in August, 1863. The water from the Dhuis was introduced into the reservoir in October, 1865, and the water from the Marne in January, 1866. The reservoir was most carefully constructed. Its failure would be attended with disastrous consequences, from its proximity to a dense population.

Some of the more important details of this reservoir are as follows: *

The shape of the upper reservoir is a semicircle, united with a rectangle. The diameter of the semicircle, which is 188 meters (617 ft.), forms the long side of the rectangle, whose other dimension is 42·5 meters (139·4 ft.) It is divided in two equal and symmetrical compartments by a division wall, following the radius perpendicular to the long side of the rectangle. The walls of the perimeter have a thickness of 1·4 meters (4·6 ft.) at top. The interior batter is 1 in 5 for the portion of the wall below the earth. Above the surface the exterior face is vertical. The interior faces are vertical, but are joined with the bottom by an arc 2 meters (6 6 ft.) in radius. The bottom is formed by a system of semicircular groined arches, for the part which covers the reservoir of the Marne, and in segmental groined arches for the other portions.

The intrados of these latter rests upon the marl or clay. The arches are of rubble masonry, 35 cm. (14 in) thick at the key. The reservoir is covered by groined arches, composed of two courses of bricks laid flat in cement. They rest upon pillars, 60 cm. (2 ft.) square and 6 meters (20 ft.) between centers. These pillars rest upon those forming the foundations of the bottom. The brick arches are about 8 cm. (3¼ in.) in thickness, including the plastering. They are covered by a layer of earth and turf, 40 cm. (16 in.) thick. The effluent pipes are 1 meter (39·4 in.) in diameter, and are so arranged that the supply may be drawn from either compartment or from the aqueduct. This reservoir may be emptied into that of the Marne, and its overflow pipe, which is placed 5 meters (16·4 ft.) above the bottom, also discharges into the latter reservoir.

The reservoir for the water from the Marne occupies only the central portion of the sub-basement of the upper reservoir. Its form is a rectangle, whose larger dimension, parallel with the front, is 104 meters (341 ft.), the other dimension being 90 meters (295 ft.) It is divided into two equal and symmetrical compartments by the division wall above mentioned. The inclosing walls are placed in the middle, and follow the direction of ranges of arches supporting the upper bottom. They are 1·2 meters (3·9 ft.) thick, with vertical faces; the interior face being joined with the bottom by an arc 2 meters (6·6 ft.) in radius. Their top forms a gallery, which allows free passage around the basins. The bottom follows the natural surface of the gypsum; its thickness being 30 cm. (1 ft.) The pillars which support the arches are 1·25 meters (4·1 ft.) square at the springs and 1·75 meters (5·7 ft.) at the bottom. The influent pipes are arranged to discharge into either or both compartments at pleasure. The effluent pipe is 80 cm. (31·5 in.) in diameter, and is so arranged that the supply may be furnished by either or both compartments. The walls are of rubble masonry. The interior surfaces are plastered with cement mortar.

Reservoir of Belleville.—This reservoir† is situated, at a higher elevation than the one at Menilmontant, on the hill at Belleville. It is designed in two stories and four compartments, but only one-half has been constructed. The upper compartment, of the capacity of 6,239 cubic meters (1,600,000 gals.), receives the water from the Dhuis. Its overflow is at the elevation 134·40 meters (441 ft.) The lower compartment is supplied by the water of the Marne; its capacity is 11,765 cubic meters (3,100,000 gals.) and its overflow is at the elevation 131·10 meters (430 ft.)

This reservoir occupies a very threatening position. It is entirely above ground, and is built upon a steep hill of fine sand. The greatest care was taken in its construction. Standing upon such a foundation, it is exposed to peculiar danger in case of accident, and the consequences of its failure would be incalculable. It was begun in September, 1863, and was finished in December, 1864. Including the residence of the custodians, it cost about 26 francs per cubic meter of useful capacity.

Reservoir of Montrouge.—The capacity of this reservoir is 300,000 cubic meters (79,250,000 gals.) It was constructed on the same system as those at Menilmontant and Belleville, and cost about 20 francs per cubic meter of water stored. It is in two stories, each of which is divided into two compartments. The reservoir is rectangular and its details are similar to those of the reservoir of Menilmontant. It is supplied with water from the Vanne and contains about three times the average daily discharge of the aqueduct from that river.

GENERAL CONCLUSIONS.

The question as to the necessity of covering a reservoir must mainly depend upon local requirements and conditions. As a general guide, it may be said that if the supply is from subterranean sources, or if it must be stored after being filtered, a covered reservoir is necessary, and that when a reservoir is amid smoky surroundings it should be covered. If the supply is from a river or lake, a covering is desirable, if the reservoir must needs be shallow. If the reservoir is deep, of large capacity, and not amid smoky surroundings, the necessity for covering diminishes and the question merges into one of cost. In the case of large storage reservoirs the expense of covering is generally prohibitory.

The best and most usual method of covering is by arches of masonry or brickwork, coated on the top with asphalt, and covered with two or three feet of earth, which may be turfed. Ventilation is important.

DISCUSSION.

The President. The subject is now open for discussion.

Mr. Allis. I should like to ask how the foundations were built for that reservoir which was placed on the sand.

Mr. Swan. The description of the reservoir I had access to did not go into details. The hill was formed of fine sand, which might have been wind-blown, and although the details would be interesting, I am unable to go into them at present.

Mr. Fitzgerald. I think we must have all enjoyed this paper on covered reservoirs. The subject is certainly one of great importance, and I believe it will attract more and more attention in this country as time goes on. I have always been, or at least for eight or ten years, an advocate of covered reservoirs for small supplies. I think perhaps the town of Brookline, which is now seriously considering the subject, will be the pioneer in the matter of covered reservoirs in this country. Certainly, there is great necessity in Brookline for something of the sort. I am sorry Mr. Forbes is not here, for he could tell you how serious the trouble with the water has been because of the exposure to the air and light. Perhaps Mr. Swan can give us some statistics in regard to the cost per gallon of the reservoirs of which he has spoken in his paper. I think it was stated the cost per cubic meter was 26 francs—a little over five dollars. I should like to know if he has any other figures of the kind that he can give us.

Mr. Swan. The figures of cost are given in that way for the French reservoirs. The figures given for some English reservoirs are £5,000 per million gallons of useful capacity.

Mr. Fitzgerald. There is another question I should like to ask the writer of the paper, and that is, if there are many of these circular reservoirs with annular spaces which are arched over, and also whether that is the favorite form of construction on the other side of the water?

Mr. Swan. I only think of two, and they are both in the vicinity of London. One is covered with rings of masonry arches, springing from wrought iron girders, bent into rings of great diameter and resting upon brick piers; and the other is covered with arches of hollow bricks resting upon iron beams, which reach from the center pier to the sides. They were originally open reservoirs and were afterward covered.

Mr. Hawes. Does this covering of reservoirs interfere any with the aeration of the water? We have had a very interesting and convincing paper on that subject, and now we are told that we ought to cover the reservoirs. Isn't it necessary to have the sunlight in the aeration of the water, and don't the two things conflict? Here we have very strong arguments in favor of aeration, and then arguments equally strong for covering the reservoirs.

Mr. Swan. The aeration of the water is provided for, to a certain extent, by means of the ventilating chimneys. The introduction of the sunlight would introduce a disturbing element which would cause the development of vegetation, and neutralize the benefit which would be derived from covering the reservoir. I do not think the two things are necessarily to be associated.

Mr. Hawes. I would like to have Mr. Babcock's opinion on that.

Mr. Babcock. Aeration is a chemical process, and I do not see where the connection between the action of the sun and aeration comes in at all.

Mr. Hawes. Don't you get the heat of the sun in your aeration* process fully as much as any other element?

Mr. Babcock. No, sir: the heat of the sun is not necessarily an adjunct to a chemical process. Aeration would go on just as well in the dark as in the light.

Mr. Hawes. Would it be as purifying as in the sunlight?

Mr. Babcock. I think it would be better without the influence of the sun than it would with it. We know very well that subterranean sources of supply are considered pure, and the general conclusion is that it is due to aeration in this way: That the particles of air permeate the earth, and the water, in passing through it, takes up the oxygen, and the chemical process goes on. I do not see any connection between the action of the sun and aeration, which is purely a chemical process.

Mr. Tidd. I suppose it is a well known fact among all who have anything to do with subterranean water, that it is more aerated than the water in streams and ponds. Those of us who have anything to do with the pumping of it know that we experience more trouble with it than with any other water, on account of the accumulation of air in the vacuum chamber—the water being so much aerated when it comes under the vacuum, that the air is extracted till it fills the vacuum chamber to such an extent that it comes through the pumps in bunches, and that is one of the worst obstacles we have to contend with. As Mr. Babcock says, I can see no connection between aeration and sunlight. My observation is that the water can be aerated in the darkest places that can be conceived of.

Mr. Babcock. I seem to have another ally to help me carry my point.

Mr. Rice. Isn't it questionable whether the means Mr. Swan speaks of as being adopted in the reservoirs he refers to for producing aeration are effective or not? He says it is done by means of chimneys. These chimneys are simply openings by which there is connection between the inner air immediately covering the surface of the water and the outer air of the atmosphere. Now, is there any way of producing the circulation of the air? Chimneys, it seems to me, are vents, but are they ventilators? They let the air in, but do they provide means to induce it to go in? Air simply in contact with the surface of the water is not going to mix to any great extent with the water itself. That can only be done by agitating the water, or by, in some manner, passing the air beneath the surface of the water, and then, by its own buoyancy, it will pass up through it, and thereby communicate or disseminate itself through the particles of the water. I do not see how the mere presence of chimneys can aerate the water.

Mr. Fitzgerald. The water taken from a filter gallery, as in the case of Brookline, of course, we all know, is remarkably pure, and the main thing is to be able to deliver it to the consumer in the same condition. If it is exposed in an open reservoir, it rapidly deteriorates, and the only practical way to obviate that is to have a covered reservoir, not too large in capacity, so that there can be a very quick circulation of the water in the reservoir. I suppose the necessity for aeration in such a case is comparatively small. It seems to me the only object of chimneys is to provide for a certain amount of circulation of air over the water. In regard to the question that Mr. Tidd has raised, which I think is an important and interesting one, as to the amount of air or oxygen combined with water in natural filter galleries, I would like to ask Prof. Drown, who has made a great many analyses throughout Massachusetts, if he has found that water from underground sources has more oxygen in it than water in open places has.

Prof. Drown. It has not been within the scheme of the analyses made under the direction of the Massachusetts State Board of Health to determine the oxygen in waters. I may remark that there is a little misconception with regard to the aeration of waters and what it really means. If a water is perfectly pure, that is to say, contains no organic matter, there is no particular object, as I see, in aerating it; in fact, the aeration will generally take care of itself. If you agitate water it will take up the air rather more quickly than if it is only exposed on the surface, but at the same time, water that contained no air, if exposed to air on the surface without agitation, would in time take up its due and normal amount. Now, if we have a ground water from which the organic matter has already been removed by filtration, and which is fairly well aerated, as many of such waters are, certainly shallow ones are, there would be no object while storing it in a covered reservoir to give it such access to the air. The amount of air that will remain in it is dependent upon the temperature; the higher the temperature the less air, the lower the temperature the more air. In aerating surface waters the idea is oxidation. If you have a surface water which is well aerated and perfectly pure, that is to say, reasonably free from organic matter, as the mountain stream would be, there is no need to aerate it, for there is nothing to oxidize.

Now, when these waters get into open reservoirs, as has been explained before the Association heretofore by Mr. Stearns, it is there an entirely different matter. That is to say, the growths are probably dependent upon substances in ground waters which are not present in surface waters. I am somewhat in doubt as to the influence of the brown coloring matter in the surface waters, whether that prevents the growths which we find in the clear filtered waters when confined in uncovered reservoirs, and which is a matter of common observation. But, certainly, the nitrites which we find very largely in ground waters supply the food for the algæ, which grow and decompose, and probably to this cause is due the offensive smell in the waters that come from this source. Surface waters, when contained in large open reservoirs, of large capacity and of great depth, do not develop the class of odors which we associate with the uncovered reservoirs containing ground waters. I think this distinction ought not to be overlooked, that the disagreeable odor in ground waters in uncovered reservoirs is not that unpleasant odor, and has no similarity with it, so far as my experience goes, that we find in surface waters contained in large ponds.

Mr. Fitzgerald. If what Mr. Babcock has stated here is correct, and aeration of the water by passing over weirs does remove the color, it is of extreme value to the profession to know it.

Mr. Babcock. In the case of my canal, we have a precipitation in the ponds as well as in the canal. Of course, the influence of the oxygen upon the matter held in suspension creates a perceptible change in the precipitate.

[Continued from SUPPLEMENT, No. 669, page 10686.]

ON VARIABLE LOAD, INTERNAL FRICTION, AND ENGINE SPEED AND WORK.*

By ROBERT H. THURSTON, Ithaca, New York, Member of the Society.

FIG. 7 is especially interesting and instructive as exhibiting the variation of internal friction of engine with change of engine speed. The plate shows this variation as determined by test of four engines: the Jarvis engine, under two sets of conditions; the straight line engine; the 8 × 12 automatic engine; and the tandem compound engine. The first named, when working unloaded, gradually increases its friction resistance as speed increases, irregularly, but approximately as a direct function of the speed, and gives a lower total at all speeds than the loaded engine at similar speeds. The difference is small, but is sufficient to be easily detected and measured. The same engine, when loaded, gives an increase of internal friction proportionally with increase of speed, up to about 500 revolutions per minute, then, changing its rate of increase, preserves the new rate up to its limit of velocity, above 600 revolutions per minute. The speed attained light, 912 revolutions, is probably the highest speed at which any engine has ever yet been given a systematic trial to determine these quantities. Curves 1 and 2 of the straight line engine are irregular, and too much so to reveal any definite law, taken by themselves, but, taken with the other evidence presented, may be considered as fully corroboratory of the conclusions deduced. Test No. 3 gives a very regular and satisfactory curve, and this accords perfectly with the others in exhibiting the law of variation of friction with engine speed. The full line drawn through this group of observations is considered as fairly representative of the mean result of all tests on this engine, and is a straight line, the representative of the law previously discovered and stated. The curve for the 8 × 12 automatic engine is anomalous, and differs from every other curve obtained, in falling with rising speed. It is evident that this engine differs, in some respects, from all ordinary engines in its law of variation of internal friction with engine speed. The smoothness of the curve would indicate that this is a real attribute of this engine, and not a mere accident of the time or of the construction of the machine. It would be interesting to push the trials of this engine farther, and to ascertain what is the final outcome of this apparent anomaly at higher speeds, and also to learn where the lower limit of the curve comes into view. The tandem

* Debauve. Manuel de l'ingenieur des ponts et chaussees, fasc. 16.
† Belgrand, *loc. cit.*

* Evidently aeration is here confounded with oxidation.
Experiments by the English River Pollution Commissioners show that oxidation is most active in sunshine and almost ceases at night.—Editor.

* A paper presented at the eighteenth meeting, Scranton, 1888, American Society of Mechanical Engineers. Advance sheets from Volume x., Transactions.

compound shows precisely the same general law as the other forms of engine, but it is subject to less variation than any other, the curve slowly rising, as the speed increases, throughout the whole range of experiment.

All these variations of engine friction have an important bearing upon the theory of the true commercial efficiency of engines. It is so important a matter that no correct or satisfactory theory of the steam engine can be constructed until the influence of this form of loss and waste can be determined and can be introduced into the general treatment of that subject. There thus remains for investigation the mathematical theory of efficiencies of the steam engine as affected by friction wastes, and the determination of the conditions of maximum total and commercial efficiency for every engine to which it may be attempted to apply that theory. The solution of the problems thus arising in the introduction of the more commonly employed engines has an extraordinary importance for the engineer, and especially for the builder and for the user. Neither can intelligently select and operate an engine in any given locality, or under any given set of external conditions, so as to secure highest efficiency, without first solving this class of problems in relation to that engine or class of engines. Rankine's graphical method, as modified by the writer, and as applied to modern engines in the manner shown in earlier papers presented to the American Society of Mechanical Engineers, supplied the most convenient and satisfactory method of effecting the solution of these problems.*

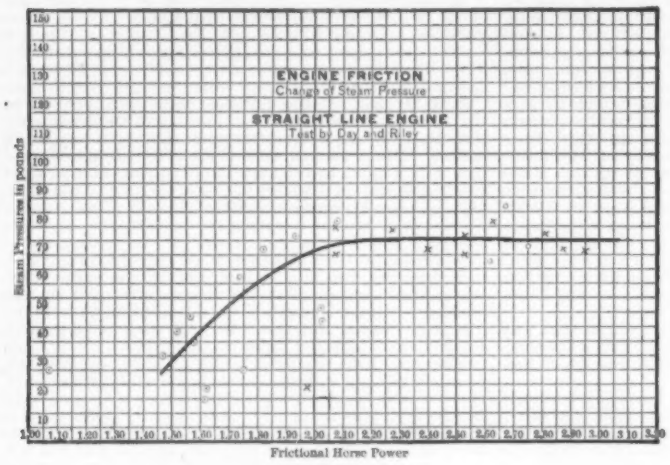


FIG. 6.

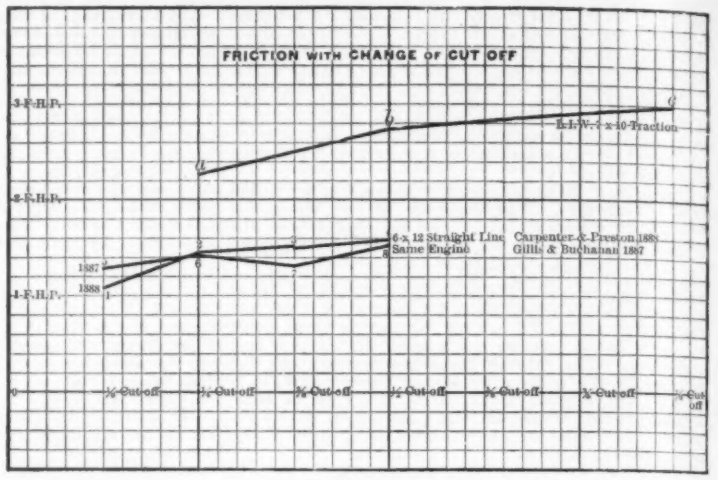


FIG. 8.

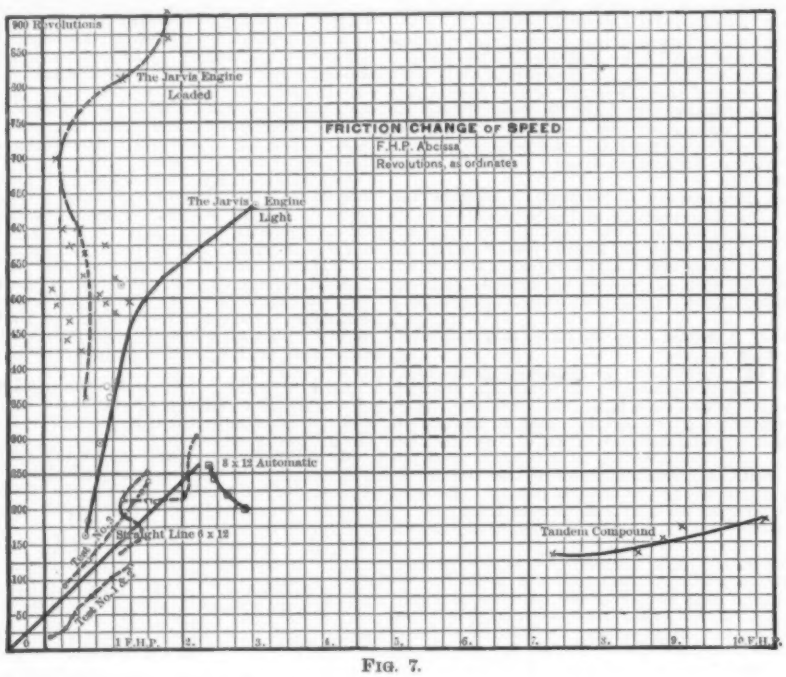


FIG. 7.

Fig. 8 similarly illustrates the variation of engine friction with variation of the point of cut-off and ratio of expansion. In all three cases taken, the variation of internal resistance of engine is visibly altered by the variation of the expansion, slowly but observably rising with diminishing expansion. The same engine, tested by the two pairs of observers, in 1887 and 1888, shows different absolute magnitudes of friction, the engine having had a year's work in the interval, but the law of variation is the same and the rate of variation is nearly equal in both cases, although the friction is seen to be more nearly constant in the first set of trials. In the third curve also, that in which the work on the 7 × 10 traction engine is illustrated, the same law and the same rate of variation shown by the first of these trials, 1887, are exhibited. All show plainly the fact that, other things equal, the friction of the engine varies slightly with change of ratio of expansion, the amount increasing as the point of cut-off is advanced and the engine is set to "follow" further. It must be kept in mind, however, that the ratio of friction of engine to total power of engine is continually varying in the opposite direction, and it does not at all follow from these observations, as here graphically illustrated, that the shorter cut-off and lower powers of engine are, on the whole, more economical than the higher. The true point of maximum economy and efficiency, all conditions being regarded, can only be ascertained by the application of the determined facts in the complete theory of the several efficiencies of the engines studied.

Fig. 9 is the graphical summary of the work done to ascertain the method and extent of variation of the friction of the engine with change of load, other conditions being, so far as possible, retained constant. The lowest curve on the plate is that obtained from the work on the Jarvis engine, and is considerably lower than any other, absolutely and relatively. It is a straight line, is parallel to the axis of abscissæ, and indicates constant waste by friction, at all loads and powers. The next curve is that of the 8 × 12 automatic engine, which is much more variable and less satisfactory as a measure of the true loss; but it gives a mean, as shown by the full line, very nearly representative of constant friction; the same is true of the 7 × 10 traction engine and of the 7 × 12 straight line engine. All give a mean which is practically independent of the power exerted by the engine. The widest range of work is that obtained with the compound condensing engine, and extends from zero up to nearly 100 H. P., the brake being the measure. This also gives some irregularity of result; but its mean is a constant at all

* Trans., vol. ii., p. 125; vol. ii., p. 245.

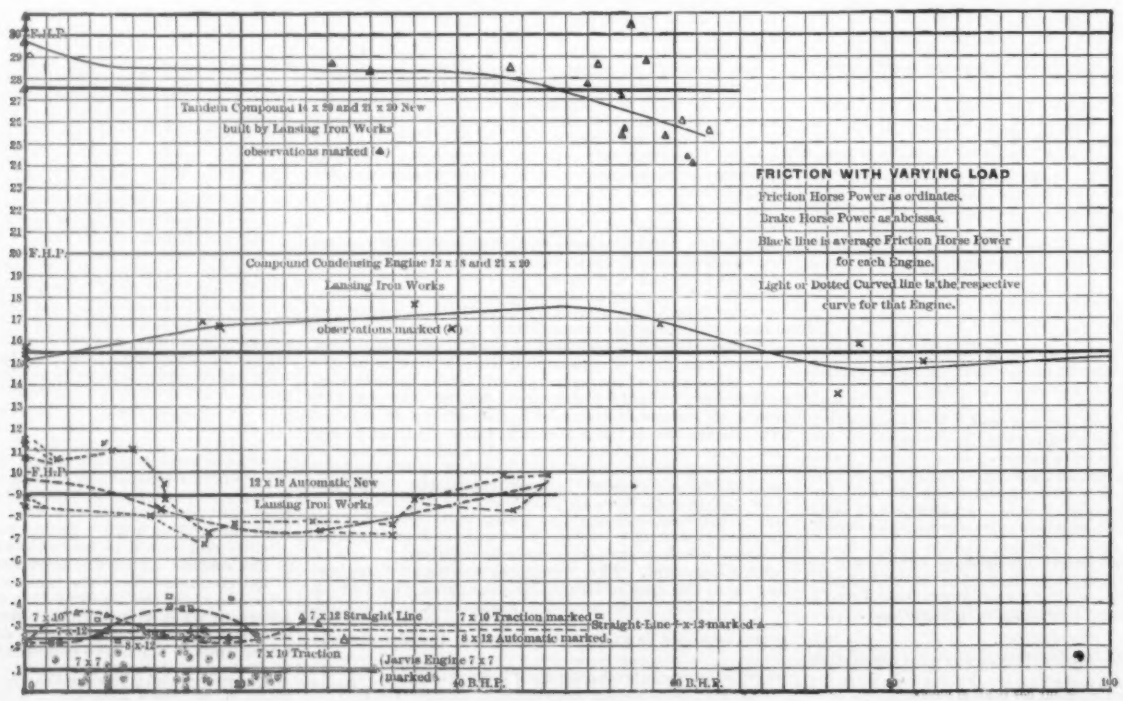

F.H.P.
Tandem Compound 14 x 20 and 21 x 30 New
built by Lansing Iron Works
observations marked (▲)
FRICTION WITH VARYING LOAD
Friction Horse Power as ordinates.
Brake Horse Power as abcissæ.
Black line is average Friction Horse Power
for each Engine.
Light or Dotted Curved line is the respective
curve for that Engine.
Compound Condensing Engine 12 x 18 and 21 x 30
Lansing Iron Works
observations marked (×)
12 x 18 Automatic New
Lansing Iron Works
7 x 12 Straight Line
7 x 10 Traction marked ⊠
Straight-Line 7-x-12 marked ⊟
8 x 12 Automatic marked
7 x 10 Traction
(Jarvis Engine 7 x 7
marked ⊙
40 B.H.P.
60 B.H.P.
100

FIG. 9.

Tandem Compound Engine
of the
DELTA LUMBER COMPANY
Built by the
LANSING IRON AND ENGINE WORKS

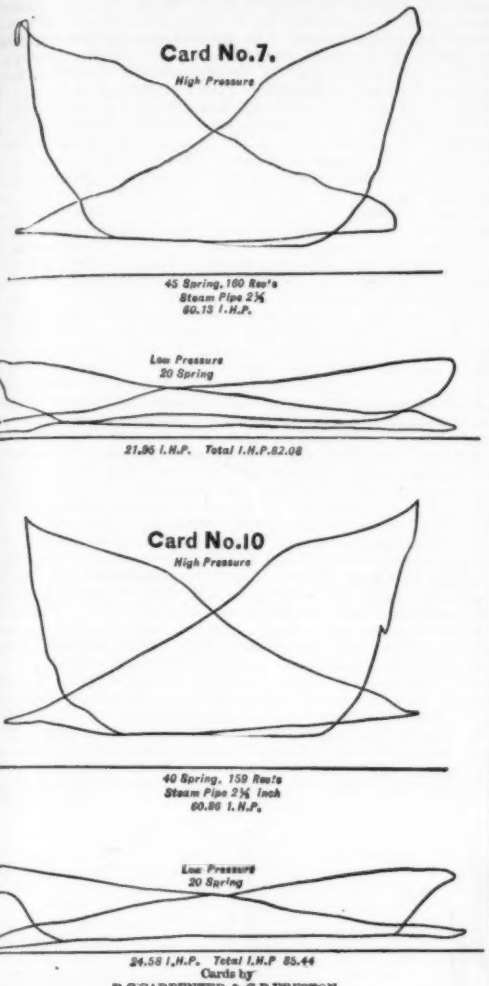


FIG. 10.

Tandem Compound Engine
of the
DELTA LUMBER COMPANY
Built by the
LANSING IRON AND ENGINE WORKS

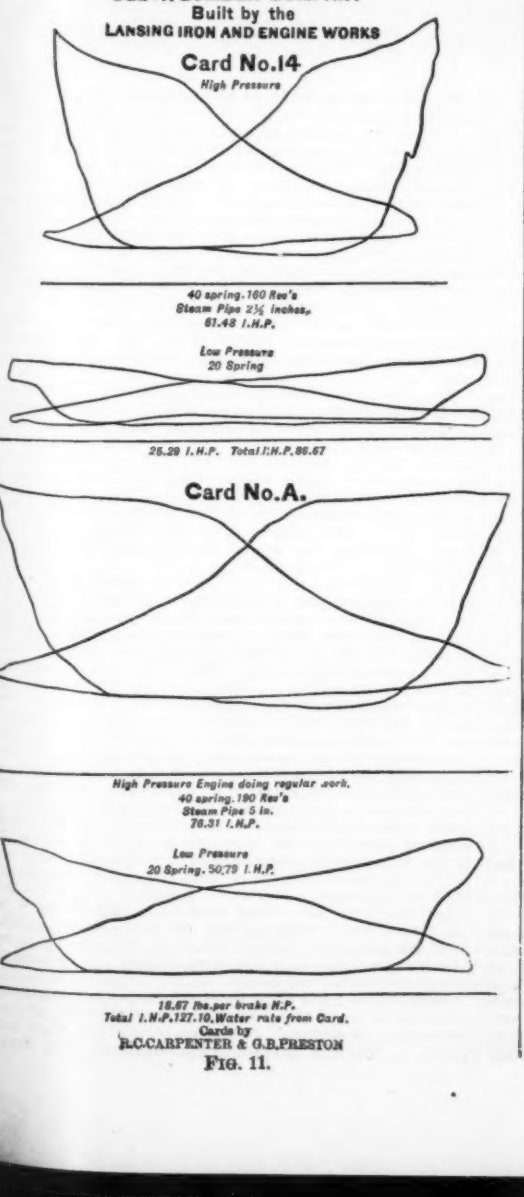


FIG. 11.

powers, and is independent of the load on the engine, so far as can be detected in this series of observations. Finally, the compound tandem engine, a new engine, naturally gives a high measure, comparatively, of the internal loss by friction; but the law is seen to be nearly the same for variation of load, and its operation confirms the deductions previously drawn from all other work of this character which the writer has been able to offer. In both of the compound engines, however, there is some evidence of a tendency to reduce friction slightly as the power is increased, a change contrary in direction to that detected in other cases; but in neither set of examples is this variation great. (See Figs. 10 and 11.)

TABLE X.

THE JARVIS ENGINE. 7"×7".

Friction with speed and load variable.

No governor. Speed varied by the throttle. Steam pressure constant at 80 lb. Trial No. 2.

No. of Card.	Revolutions of Engine.	M. E. P. Head.	M. E. P. Crank.	I. H. P. Head.	I. H. P. Crank.	Total.	Brake H. P.	Friction H. P.
1	475	6·9	9·7	2·30	2·42	4·72	3·44	1 25
2	475	14·9	16·6	4·95	5·40	10·45	8·55	1·80
3	495	8·9	9·9	3·09	2·94	6·03	5·61	0·42
4	495	23·7	24·4	8·04	7·9	15·94	14·1	1·84
5*b*	495	29·4	27·4	10·15	6·80	16·95	15·35	1·60
6	817	31·7	29·0	18·09	15·57	33·66	32·60	1·06
7	912	13·5	11·0	8·7	6·6	15·3	13·6	1·7
A	602	11·2	10·4	4·0	4·4	8·4	?	... ..
B	602	22·8	24·6	8·1	9·2	17·3	16·8	0·5
C	602	18·0	18·6	7·37	7·39	14·75	?	... ..
D	700	16·4	17·0	8·09	7·57	15·67	15·44	0·23
E	874	17·8	18·0	10·61	10·38	20·99	19·85	1·74
F	703	17·5	18·0	8·36	8 35	16·71	14·46	2·25

TABLE XI.

THE JARVIS ENGINE.

Friction with load and speed variable.

Steam pressure constant.

Trial No. 3.

No. of Card	Rev's of engine.	M. E. P. Head.	M. E. P. Crank.	I. H. P. Head.	I. H. P. Crank.	I. H. P. Total.	Brake H. P.	Frict'n H. P.
1	355	13·3	13·5	3·47	3·16	6·63	5·91	0·72
2	355	13·5	13·5	3·24	3·16	6·40	5·91	0·49
3	427	14·3	14·8	4·15	4·20	8·35	7·79	0·56
4	443	13·5	12·5	4·08	3·67	7·75	7·41	0·34
5	513	11·3	11·3	3·96	3·85	7·81	7·71	0·10
6	483	13·2	13·0	4·94	3·85	8·79	7·76	1·03
7	576	13·5	11·3	5·31	4·17	9·48	9·01	0·47
8	576	14·5	11·2	5·69	4·97	10·66	9·59	1·07
9	576	22·0	22·7	8·62	8·73	17·35	16·38	0·47
10	576	23·5	25·5	9·21	9·69	18·90	17·28	1·62
11	469	22·5	26·5	7·18	8·20	15·38	14·94	0·44
13	481	35·0	84·3	11·18	11·76	22·94	22·74	0·20
14	481	34·2	36·3	12·67	11·89	24·56	23·70	0·86
16	507	33·5	36·0	11·55	12·04	23·59	22·62	0·97
17	507	29·6	31·8	10·63	10·23	20·86	20·25	0·61
18	507	31·0	35·4	10·67	11·82	22·59	21·93	0·66
19	532	6·0	10·2	2·72	3·48	6·20	5·60	0·60
20	527	10·2	11·7	3·64	4·09	7·73	6·65	1·08
21	522	19·2	21·3	6·96	7·42	14·38	14·02	0·36
22	522	21·0	23·4	7·49	8·48	15·97	14·99	0·98

See Fig. 10.

TABLE XII.

TEST BY R. C. CARPENTER AND J. B. BERGER, 1887.
FRICTION WITH CHANGE OF SPEED.

Straight Line Engine, 6"×12" *cut-off at stroke.*

Governed by the Throttle.

No. 1.

No. of Card.	Revolutions per minute.	I. H. P.	Brake H. P.	Friction H. P.
1	20·5	0·449	0·369	0·080
2	28·0	0·801	0·504	0·297
3	152·0	3·556	2·888	0·768
4	175·0	5·650	3·150	0·963
5	215·0	4·113	3·970	1·680

TABLE XIII.

TEST BY R. C. CARPENTER AND J. B. BERGER, 1887.
FRICTION WITH CHANGE OF SPEED.

Straight Line Engine, 6"×12".

Trial No. 2.

No. of Card.	Revolutions.	I. H. P.	Brake H. P.	Friction H.P.
1	137	9·193	8·636	0·557
2	136	9·583	8·500	1·083
4	165	11·244	9·570	1·674
5	165	10·703	9·731	0·968
7	192	12·101	10·944	1·157
8	80	4·982	4·240	0·742
9	48	2·979	2·592	0·387
10	100	6·555	5·600	0·955
11	120	7·647	6·360	1·287
12	130	7·718	6·695	1·023
13	171	9·447	8·208	1·239
14	217	12·238	10·190	2·039
15	219	12·545	11·059	1·486
16	229	11·682	10·534	1·128
17	252	11·836	10·332	1·504
18	241	11·574	9·640	1·934
19	266	11·626	9·709	1·917
20	315	13·621	11·182	2·439

TABLE XIV.

EFFECT OF SPEED ON ENGINE FRICTION.

Straight Line Engine, 6"×12". Trial No. 3, Engine Light.*

Test by R. C. Carpenter and J. B. Berger, 1887.

No. on Card.	Revolutions of Engine.	I. H. P.
A	92	0·32
B	238	1·39
C	245	1·51
D	214	1·23

* For details of last three tests, see paper cclxv., vol. ix., American Society Mechanical Engineers.

TABLE XV.

STRAIGHT LINE ENGINE, 6⅞" × 12".

Friction with Change of Load.

No. of Card.	Revolutions per Minute.	Steam Pressure—Pounds.	Brake H. P.	I. H. P.	Frictional H. P.	Frictional H. P. Reduced for Speed of 250 Revolutions.
1	282	19	0·0	2·26	2·26	1 97
2	288	66	4·87	8·43	3·56	3·02
3	286	66	7·61	10·95	3·34	2·87
4	284	65	10·30	12·93	2·93	2·54
5	285	71	13·10	15·99	2·89	2·54
6	284	76	15·30	18·79	2·99	2·63
7	284	74	18·15	20·73	2·58	2·28
8	280	67	21·00	23·73	2·73	2·40
9	279	65	23·61	25·95	2·34	2·07
10	280	75	26·39	29·95	2·86	2·08
11	280	72	29·03	32·22	3·19	2·81

TABLE XVI.

TRIAL BY DAY AND RILEY, 1886.

Straight Line Engine, 6⅞" × 12".

Friction with Varying Steam Pressure.

No. of Card.	Revolutions.	Steam Pressure.	I. H. P.	Mean F. H. P.	Equivalent I. H. P. for 250 Rev.
1	250	25	6·01	1·07	1·07
2	271	39	6·52	1·65	1·52
3	285	42	7·17	2·31	2·03
4	280	46	7·08	2·26	2·01
5	271	58	6·81	1·88	1·74
6	289	63	7·85	3·03	2·61
7	286	68	7·77	3·13	2·75
8	293	77	7·88	2·44	2·08
9	296	82	7·87	3·14	2·67
10	275	71	2·10	2·13	2·94
11	279	66½	1·995	2·03	1·81
12	277	44	1·708	1·76	1·56
13	275	35	1·71	1·73	1·57
14	275	30	1·613	1·61	1·46
15	272	25	1·876	1·91	1·75
16	270	19	1·724	1·75	1·62
17	270	15	1·712	1·74	1·61

TABLE XVII.

MITCEEL'S AND ALDRICH'S EXPERIMENTS OF 1884.

Straight Line Engine, 8" × 14".

Friction with Change of Load.*

No. of Card.	Boiler Pressure.	Revolutions.	Brake H. P.	I. H. P.	Frictional H. P.
1	50	332	4·06	7·41	3·35
2	65	229	4·98	7·58	2·60
3	63	230	6·00	10·00	4·00
4	69	230	7·00	10 27	3·27
5	73	230	8·10	11·75	3·65
6	77	230	9·00	12·70	3·70
7	75	230	10·00	14·02	4·02
8	80	230	11·00	14·78	3·78
9	80	230	12·00	15·17	3·17
10	85	230	13·00	15·96	2·96
11	75	230	13·00	16·86	2·86
12	70	230	15·00	17·80	2·80
13	72	231	20·10	22·07	1·97
14	75	230	25·00	28·31	3·31
15	60	229	29·55	33·04	3·40
16	58	229	34·86	37·20	2·34
17	70	229	39·85	43·04	3·19
18	85	230	45·00	47·79	2·78
19	90	230	50·00	52·60	2·60
20	85	230	55·00	57·54	2·54

* For details of tests by Day and Riley and Mitchel and Aldrich, see paper ccviii., vol. vii., American Society Mechanical Engineers.

SHRINKAGE ALLOWANCE FOR RAILWAY TIRES.

BREAKAGES of tires on railways may, to some extent, be accounted for by the fact that many tires are put on with too great an allowance for shrinkage. This keeps the tire in severe tension all the time, and is a constant source of danger. There is every reason to believe that the allowances established about a year ago by the Master Mechanics' Association are about right. They are, for inside diameters of tire, as follows:

38 inches less	0·040 inch.	56 inches less	0·060 inch.
44 " "	0·047 "	62 " "	0·066 "
50 " "	0·053 "	66 " "	0·070 "

ON THE PROPULSION OF SHIPS BY AIR PROPELLERS.*

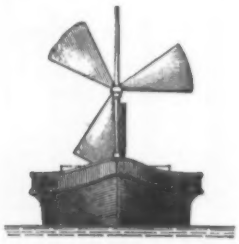
By H. C. VOGT.

IF ships could be pulled through the water, instead of being driven by means of the ordinary propellers now in use, then a saving, on an average, of 40 per cent. in engine power would be gained, because both the screw and the paddle push the sustaining water from the ship, and thus augment its resistance, and it has been found by experiment that the thrust of the propeller surpasses the pull of a tow rope, on an average, by 40 per cent. to obtain the same speed in the same vessel.

A further cause to the increase of resistance is that bow and stern waves are intensified by the increased speed which the screw communicates to the stream lines round the ship, and the latter consequently sinks down into the trough between these waves, and causes the resistance to vary with the third and sometimes fourth power of the speed, whereas it should only increase with the second power.

To be efficient, the screw requires a ship of special type, with water lines arranged to insure the screw acting in solid water; large ships cannot, like torpedo boats, have their screw shafts carried out along the line of the keel, so as to keep the propeller clear of the ship; hence the form and proportions of the ship have to be determined with reference to the propeller, and not to the questions of easy passage through the water and of seaworthiness. Formerly, the length of ships was three to four times the breadth, now the length is ten times the breadth. Both proportions cannot be correct; the discrepancy is, in fact, the consequence of the existing mode of propulsion. If the driving power could be applied above the deck of a ship, as in towing, then the following advantages could be gained: 1, A saving amounting to 40 per cent. in engine power by eliminating the disturbing action of the screw; 2, the form of ship could be determined with reference to least resistance and seaworthiness only, and the division in watertight compartments could be complete; 3, the change in trim will be less disadvantageous when the power is applied above the deck than below the center of gravity; 4, the vibrations caused by the screw propeller, which are destructive to the ship and most unpleasant to those on board, will be avoided; 5, the proposed air propeller will utilize the natural wind power.

The mode to accomplish these objects is to propel the ship by means of revolving sails acting in the air. The air propeller is, in its outer shape, somewhat similar to the ordinary water screw, with sails or blades made of thin sheet steel, having the greatest width near the circumference. The pitch of the blades is capable of being varied in order to utilize the power of the wind, because nearly 80 per cent. of the winds, the whole compass round, augments the thrust of the propellers.



In order to avoid vibrations, the blades of water propellers are tapered toward the tips or near the circumference, whereas the blades or sails of the air propeller should be broadest near the circumference, because the air, being elastic, causes no vibrations. It is found in practice that for equal numbers of revolutions, equal intensity of thrust, engine power, and speed, the area of an air propeller should be about twelve times that of the water screw, but this ratio decreases somewhat as the size of the ship increases.

In nature, the difference between the areas for propellers to give equal thrusts in air and water is not nearly so great as the difference of the specific gravity of the elements would lead us to suspect. A big swan, for example, weighs 35 lb., but the wing area is only twenty-five or twenty-eight times the area of the web feet; if we suppose the horizontal resistance, when the bird swims quickly, or when it flies with a velocity thirteen times greater, to be about the same, equal, say, to 4 lb., then, when flying, in addition to the 4 lb. horizontal resistance comes the weight to be sustained; consequently the thrust of the wings must be many times greater than that of the web feet, and the difference between the areas for equal thrusts is therefore not great.

In dealing with surfaces turning round an axis there is one point of the greatest importance, namely, "the point of effort," in which the whole resistance of the surface is supposed to be concentrated. For a rectangle turning round one of its sides the point of effort is at a distance of three-quarters of the length of the other side from the axis. For the oblique surface of the blade of a screw, the point is at an average distance of two-thirds of the length of the blade from the axis. The sails of an air propeller, having their greatest width near the circumference, may be so proportioned as to have their points of effort distant three-quarters of the length of the sails from the axis.

The efficiency of an air propeller is due to the elasticity of the air, and a propeller of perfect shape would be subject to loss from friction only. If masses of air and water, endowed with equal moments, strike a plane, the impulse from the air is about twice that from the water—a fact which can be deduced from the formulæ for the resistances of the two fluids. The coefficient for air is $\frac{1}{773}$ that of the coefficient for water, although water is 770 times denser than the air.

The resistance of a centrifugal fan is, for this reason, much greater in proportion to the mass of air moved than that of a centrifugal pump in proportion to the mass of water moved, and consequently the efficiency of the fan is only about half that of the pump—a condition of things very favorable to the air propeller, which, considered as a fan, has an efficiency of only 35 per cent., whereas the efficiency is over 70 per cent. when used as a propeller.

When the wings of an air propeller rotate quickly, a rarefaction is created in front of them, because wind impinging on surfaces, and passing their rigid leading edges, as is the case with the wings of birds, draws the still air from the rear sides of the front surfaces, just as the air is drawn out of a funnel by the suction of the wind passing over its edge. In gales of wind a difference of pressure amounting to 30 lb. on the square foot may occur. When, further, a surface rotates, the pressure on the windward side is greatest near the tips, causing the air to move against the axis, while quite the reverse is the case on the leeward side; wherefore centrifugal force assists in removing the air from the latter side, making the resistance three times greater than it is when the same surface moves normally to its plane, with the same speed as the point of effort. By means of this rarefaction the air required to create a thrust is drawn to the propeller. Rarefaction, in fact, is the only means by which large masses of air can be moved toward the propeller, though not the whole pass through. In nature large masses of air are always moved by rarefaction or storm centers. The sketch giving a general idea of a ship with air propeller is exhibited to illustrate the experiments to be described.

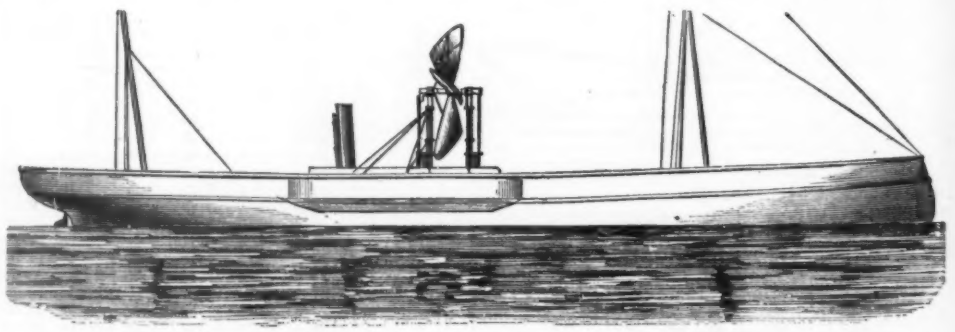
Experiments.—If a small two-bladed air propeller with blades of proper shape and curvature made of sheet steel, 1 ft. in diameter, average pitch 1 ft., ½ square foot area, and weighing 0·35 lb., is placed on a small pulley with a vertical axis, which, by means of a cord wound round the pulley, can be set in quick rotation, carrying the propeller with it, then a considerable amount of kinetic energy can be imparted to the small propeller. It is carried round by pins, the friction of which keeps the propeller down till the accelerating force ceases to act, when it is immediately released and flies up. A man of ordinary strength can give such a propeller about 70 revolutions a second, whereupon it will rise 200 ft. into the air; of this height 100 ft. are passed in less than one second after the propeller has obtained its proper speed—a fact which seems to indicate negative slip, whereas, in the experiments following, the slip sometimes amounted to from 60 to 70 per cent. Mr. Freninges, of Copenhagen, measured the efficiency of this propeller with the most minute accuracy, and found it to be 63 per cent.; that is, the work done by the propeller in raising itself through a certain height and the kinetic energy left—as it hovered a little time before beginning to fall when the highest point had been reached—is 63 per cent. of the kinetic energy attained by the 70 revolutions given to it. At 13 revolutions per second the propeller hovered, that is to say, it exerted a thrust equal to its weight, 0·35 lb.; at 52 revolutions per second the thrust was 6 lb., and it would require something like 100 foot pounds to maintain this thrust, whereas a water screw 1 ft. in diameter would do the same at 4·6 or 5 revolutions per second and 60 foot pounds of work. By way of comparison it may be stated that a tug boat tested by means of a spring balance produces a pull of about 35 lb. per indicated horse power. With equal diameters, therefore, the air propeller requires greater power to yield a given thrust than the water screw; this is due to the loss by friction caused by having to revolve eleven times quicker. But against this must be set the area of an air propeller, which should be about twelve times, and the diameter three to four times, that of the water screw; then the number of revolutions will be about equal, as also the friction, and there being no losses by shocks in the elastic air, the thrust will be even higher for the same engine power—a fact which will be demonstrated by the experiment next to be described.

The apparatus for the next experiment was made by Messrs. Dahlstrom & Lohman, engineers, of Copenhagen. An air propeller was fitted to a boat for the purpose of comparing it with the most efficient propeller known, namely, the oar, the efficiency of which is over 70 per cent., and as oars do not disturb the stream lines round the boat on account of the distance at which the blades enter the water from it, the resistance of the boat is not augmented. The boat used for the experiment was 16 ft. long by 4½ ft. beam, and the diameter of its three-winged air propeller with sails of thin sheet steel was 4½ ft., having an area of about 5 square ft.; the propeller weighed about 7 lb., and a man could drive it up to nearly four revolutions per second, at which a speed, in calm weather, of rather over three knots was obtained. A thrust of 10 lb. required an effort of about 100 ft. pounds. Intrinsically an air propeller is not inferior to the oar, but when manual power is used to turn the former, multiplying gear of some kind is indispensable, and a considerable loss results in consequence.

The difference in speed which a man could obtain by means of either the air propeller or the oar was not great. With a side wind the air propeller was rather superior to the oar. The experiments just described were carried on in September, October, and November, 1887, and the case never happened where a man by exerting himself could not pull against a gale, and by changing the pitch it was always possible to maintain the same speed of revolution, whatever the strength of the wind and its direction relatively to the boat might be. The speed of the points of effort of the sails was 35 ft. per second, and a gale the direction of which was exactly opposite to the course of the boat, of about 45 ft. per second, caused the resultant wind to impinge, as though sailing 3·5 points from the wind with stationary sails. When the course of the boat was turned 3·5 points from the wind, the thrust of the propeller began to increase above what it was in calm weather.

Before the experiment just described, two trials with steam power on a much larger scale were carried out, but the propellers, the sails of which were of ordinary canvas, were several times too large in area. The first of these experiments was undertaken by Messrs. Dahlstrom & Lohman, the other by the Royal Dockyard in Copenhagen, on the recommendation of Mr. Ram, the Minister of Marine. Three years ago a launch 30 ft. long, 5½ ft. beam, was fitted with a propeller 8½ ft. in diameter, having 24 square feet area distributed over two ordinary canvas sails, the pitch of which could be varied by means of sheets. The engine had one vertical cylinder with a stroke of 14 in., and piston area of 5 sq. in.; on the end of the horizontal propeller axis was a crank 7 in. long, and the propeller was thus driven directly, and with a boiler pressure of 80 lb. to 90 lb. This engine indicated 1½ horse power, and the speed obtained in calm weather was rather over 5 knots at 110 revolutions per minute, with a pitch equal to the diameter; the speed at the points of effort was 36 ft. per second. In a fresh breeze of about 25 ft. per second a speed of six knots was obtained about 7 points from the wind, but straight against it—equivalent to sailing 5 points from the wind—the speed was reduced to four knots. A gale equal in speed to that of the points of effort, or 36 ft. per second, made the resultant wind impinge just as if sailing 4 points from the wind when going straight against the gale; the speed was then reduced to 2·5 or 3 knots. Measured by a spring balance, the thrust of the propeller was, in calm weather, 36·7 lb. for one indicated horse power, or the same as that of a water screw turned by the same power. In windy weather this thrust was augmented through 75 per cent. of the directions in which the wind could blow. The launch belonging to the Royal Dockyard had a displacement of about five tons, was 31 ft. long by nearly 8 ft. beam, and with its ordinary screw could obtain a speed of 7·3 knots at 240 revolutions per minute, and 11·3 indicated horse power, the boiler pressure being 60 lb. The engine had two cylinders, each 6 in. diameter by 6 in. stroke.

The screw was removed and the same engine was made to drive an air propeller 20 ft. in diameter by means of grooved pulleys and a driving rope; to do this the engine was moved toward the bow of the launch and the boiler toward the stern. The pulley on the propeller shaft was 6½ ft. in diameter, and made exactly like the wheel of a velocipede; the driving pulley on the crank shaft was 19 in. in diameter, the engines would therefore make four revolutions to one of the propeller, but on account of the slipping of the rope on the driving pulley this ratio was not realized in practice. The air propeller had four canvas sails, with a total area of 250 square feet; the pitch was changeable by means of sheets. With that area and about 30 revolutions per minute the speed obtained was scarcely four knots, but by reducing the area to about 150 square ft., and by altering the shape of the sails, keeping them broadest near the circumference, an average speed of nearly seven knots was reached at 50 revolutions per minute, sailing in a circular course, with the strength of wind about 18 ft. per second. Straight against the same wind the speed was six knots. Later experiments have proved that the area of the sails was still six times too large.



The crew in the launch consisted of two officers, one in charge of the boat, the other taking the observations, an engineer, a stoker, a seaman, and the inventor. A great many runs were made on the measured mile, as well as beside a torpedo boat going at a known speed. In a strong wind the sails of the propeller had sometimes to be reefed, and when the velocity of the wind dead ahead equaled that of the points of effort of the sails, or 35 ft. per second—equivalent to sailing 4 points from the wind—the speed was reduced to 2·5 or 3 knots.

The official trial trip took place on the 27th of July, 1886, in the presence of the director of naval construction, K. Neilson, and other officers who followed the run in a steamer. The weather was fine, with a breeze of about 18 ft. per second. The boiler pressure was 60 lb., and the engine made 240 revolutions, indicating 11·3 horse power, but at least 2 horse power were lost by the slipping of the driving rope. The speed obtained with favorable wind directions was seven knots at 50 revolutions, and straight against the wind six knots with the same number of revolutions, but the pitch was then nearly four, due to the slow rotation; the pitch was of course reduced when not straight against the wind. The director estimated that half a knot more would have been gained if the gear had worked properly. As on previous trials, 75 per cent. of the winds increased the thrust of the propeller.

The results recorded here were not as satisfactory as they should have been. The propeller was much too large, the boat had a load of nearly 1,600 lb. more in her than when tried as an ordinary screw launch, and the propeller being of canvas, with many ropes about it, was far from the proper form, and presented a high frictional resistance.

People who have not witnessed any experiments are slow to believe in the power of going straight against the wind, yet it should be remembered that when the pitch is properly adjusted, the points of effort must,

* British Association—Section G.

at a constant number of revolutions, have a greater speed than the wind. Observers of nature must have witnessed the facility with which even small birds fly against any gale. A wind dead ahead, equal in speed to the points of effort of rotating sails, reduces their thrust nearly 60 per cent.—or by the same amount with which the driving thrust of ordinary sails is reduced, when the course is changed from wind abeam until four points from it. Such a reduction is rare even in the case of a propeller worked by manual power, and for larger propellers such a reduction would never occur, because the speed of its points of effort would be greater than any hurricane, and 3·5 points from the wind the thrust of the propeller is increased above what it is in calm weather.

PHOTOGRAPHIC OBJECTIVES.*

FACTS AND FALLACIES REGARDING THEM.

By EDWARD BAUSCH.

THE literature on photographic optics is exceedingly meager, and that which is open for study is distributed mainly in the form of papers and articles written in photographic journals. The terms "depth of focus," "distortion," "chromatic and spherical aberrations," and "visual and chemical foci" are used rather promiscuously, and I fear not always understandingly.

It is not my purpose to give you a treatise on optics pertaining to photographic lenses, but to mention those terms and give explanation of them which meet one in pursuit of photography, and draw attention to some things which, from my experience and a varied correspondence, I am led to believe are not fully understood by all. The diversity of qualities pertaining to lenses for photographic purposes is apt to be confounding, unless a person has the benefit of extended experience or study on the subject, and there is no question that the assumption of knowledge where it did not exist, or relying on statements which were not correct, have led to many errors of judgment which in turn have been the cause of disappointments, prejudices, and loss.

I therefore think that any statement of facts which are incontrovertible, because they are natural laws, will not only be fruitful of a better knowledge, but may in time lead to some unity of action in the mode of examining and testing objectives, for I venture to say that there is a necessity for this, inasmuch as different persons follow different plans, giving varying results, and few of them accomplish the complete result.

It may be best to say at the outset what the qualities are which are involved in a first class photographic objective, and which with many others are the problems for the optician to solve. They are as follows: Exact coincidence of visual and chemical foci; a formula involving such glass and curves as will give the utmost freedom from spherical and chromatic aberration; such a relation of glass and curves as will avoid internal reflections and consequent "flare" or "ghost;" length of focus; diameter of lenses; absolute homogeneity of glass, or freedom striæ or veins; grinding and polishing the various surfaces so that they shall be strictly spherical; absolute centering of lenses before and after mounting.

I cannot think that I can better show the importance of these various factors than by leading you through the process of completing a lens, omitting the minutiæ of work, and thus also showing you the difficulties which beset the path of the optician in his endeavor to reach the result. We will assume that he desires to make a medium-sized objective, of the form which is principally used to-day (a system of two symmetrical combinations), and that he has laid out in advance the formula on which he intends to construct it.

He has in his possession four plates or disks of rough and unsightly glass, two of which are crown and two flint, which are to be to him the cause of disheartening failure or gratifying success. If he has any experience at all, he will use no other than such as is warranted by the glass manufacturer, because even then he will find considerable difficulty in obtaining perfect glass. The glass comes from the manufacturer with a guarantee or not; in the latter he assumes no responsibility, while in the former he does as far as the refractive index and most glaring faults are concerned. If they are of guaranteed form, the disks have facets ground and polished on the edges on opposite sides, by means of which the maker has carefully tested the glass and by which means the optician may do the same.

I would say here in parenthesis that none of this glass is produced in this country, and none of the glass manufacturers with whom we have yet come in contact has shown any inclination to undertake to make it. We hope and feel confident that the time will come when it will be made within our borders, and when so, with the natural facilities at our disposal, we feel certain that we shall obtain a higher and more satisfactory result than exists to-day. The cost of the glass is now a very important factor in the price of the lens. The glass itself must of course conform to the formula, and often the formula must conform to such glass as it is possible to obtain.

Any variety of crown or flint may be obtained, but it has been found that the light flints and crowns give the most satisfactory results. Flints are usually the outer lenses of double combinations, and when heavy are exceedingly soft and subject to oxidation. The optician now begins to abrade the glasses, giving them approximately the form he wishes them to have, and then begins the process of grinding and polishing. Although this is done on the same general principle, the details vary with different opticians; and although the same result may be and is accomplished in different manners, it is safe to say that, if one were to follow the plan of another, he would fail. There is a peculiar touch or feeling in doing this work which it takes years of practice to acquire, and even then I find a person must be adapted to it. One might give the method of procedure down to the minutest detail, and this has often been done, and for all that a person might follow it any number of times and still fail. One thing, however, is true, that few persons have any conception of the amount of exactness which is required in this work. This remark of course applies mainly to an objective which is to be of the highest standard, and which to a certain extent varies with different opticians according to their skill, and not to such productions as may be called commercial, for the reason that the pecuniary return, and not excellence, is the paramount consideration. A certain amount of care is observed even in the cheapest forms, but these are not subjected to critical tests, and any faults which are not apparent to the purchaser are allowed to pass, which is not the case in the highest grade, where the best is none too good; the result is of course that they are inferior, varying, and unreliable, and while occasionally one may find an excellent lens among them, no reliance can be placed upon them. It has been computed that an error or variation from the spherical surfaces, for instance, so infinitesimally small that there are no mechanical means for determining it, say of $\frac{1}{100000}$ of an inch, will have a noticeable and sometimes disastrous effect in the formation of an image. We all know, from the fact that we have read it often, of the utmost exactness with which a telescope objective must be made, and the claim is generally made that because the image from the objective is magnified by the eyepiece, a greater perfection is required than in the photographic objective. I have found, however, that any lack of perfection which is noticeable by an eyepiece is as pronounced in the camera, and I therefore claim and make this empathic, that a first-class photographic objective requires as much perfection as that in the telescope or microscope, and no work spent upon it to accomplish this result is lost.

To return to our objective, we will suppose that all the surfaces have been ground and polished. This in practice means considerable. The difficulty of doing the surfaces increases out of all proportion with the increase in size, as well as the danger of scratching. It is an ordinary event to scratch a surface during the process of grinding and polishing, and nothing uncommon to do so in the last stages of the latter, when the entire work must be repeated. No matter how good a surface may otherwise be, a scratch is inadmissible; not that it does any particular harm, but an optician who takes pride in his work cannot bear it, and the customer who has to pay for it will not accept it. After polishing, the lenses are put into a lathe one by one, and centered, that is, the optical axis is found, which we know we have when on revolution of the spindle the two images which the surface gives are stationary. The edges are now ground down to the diameter of the cell in the mounting.

The next step is cementing. This is a delicate process, for although in each part of the work heat has been used, a much higher degree is required, and the danger of cracking the lenses is increased. It is no ordinary occurrence to lose lenses in this work, or, for that matter, at any point of the process. Great care must here be observed to prevent the cement from turning yellow and thus disturb the transparency of the lens and thereby cause loss of light. The lenses are next temporarily fixed in the mounting and are ready to be examined in the camera. Now comes the moment of suspense. Focusing on an object—and for this purpose I consider a large flat screen covered with printed matter containing various sizes of letters, or a large map hung against a perpendicular wall the best—the first thing which comes to our notice is the focal length of the objective. It may be one-half of that which was figured upon, or twice as long. However, if not correct, we make note of how much it varies and proceed to examine the image. This may be sharp and brilliant in the center and gradually become more indistinct as it nears the edge, and may remain indistinct near the edges under any amount of focusing; or it may have the same fading out of the image toward the edge when the central portion is sharp, but this may be brought out clear by change of focus; or the image may be such that it cannot be sharply focused at any point. There is yet one possibility, but a strong improbability, that the image may be quite sharply defined over the entire screen; this of course is the most favorable condition. After making note of whatever the appearance may be, we proceed to determine the coincidence of visual and chemical foci. As is well known, there are, photographically speaking, two sets of light rays emitted by every object. Those that form the image on the screen, and which are most perceptible, or the visual ones, are made up by the red, yellow, and orange colors of the spectrum; whereas those which make the photographed image, or the chemical rays, are formed by blue, green, and indigo, which are the least discernible, and it is a problem of some difficulty to bring both sets to form an image in one plane. To determine this, we proceed to make an exposure on a plate. Before doing this, however, we must be assured of three things: First, that the ground glass is flat; second, that the plate which we intend to use is flat; third, that the plate when exposed will be in exactly the same plane as the ground glass. I lay great stress upon these points because on them depends a reliable result, and then because with many plates and cameras these conditions are not fulfilled. If you will go through a package of plates you will find some almost perfectly flat, others that are convex, and others concave, the deviation being fully as much as one-sixteenth of an inch, and in larger plates even more.

I do not mention this in the way of finding fault with the plate manufacturers, because ordinarily and particularly when stops are used it is of little moment, and because it would be almost impossible to furnish selected flat plates at the present prices. The Eastman roll holders I have found well adapted, because the film passes over a fixed and flat back which remains constant in its relation to the ground glass. If the ground glass is flat, then flat plates should be selected, and if the ground glass be concave, then plates corresponding to it should be used. I believe that, as a rule, where care is observed, slightly concave ground glass in plates are used, because they come in this way and this form favors the lenses. The one thing, however, which should be insisted upon, and which I am sorry to say is not always the case, is that the film side of the plate should be exactly in the plane of the ground glass when it replaces it. To determine this, the following plan, which I think is used by manufacturers of cameras, is effective.

Take a straight edge and allow it to rest upon the face of the frame of the ground glass which rests against the back of the camera. Cut a small wedge of wood and insert this between the straight edge and ground glass as far as it will go, and mark the edge in line with the straight edge, when it fills up the space. Now take a plate which is suited to the plate holder and which is known to be flat, and place it in this, and by the use of the straight edge and wedge proceed as above with the ground glass. It is unnecessary to say that the marks should agree exactly, and if not, should be made to do so.

These precautions are alike necessary for the optician and photographer, whether for the purpose of determining the quality of the lens or for making comparisons between several lenses, and it is a test which every camera ought to undergo. After the plate has been exposed and developed, we may find that although we have a sharply defined image on the ground glass, the one on the plate is very indistinct, which shows that the chemical foci may be shorter or longer than the visual. To determine the extent of variation a number of exposures must be made, placing the ground glass within or beyond the visual focus until as sharp an image is obtained in the negative as on the ground glass. We now have all the principal data to enable us to proceed with the correction of the lens. First is the focal length, next the spherical aberration, then the amount of distortion, and last, but for the present most important, the difference between visual and the chemical focus.

To attempt to correct any one of these qualities will disturb the others, and not only that, they are often to such an extent antagonistic that to improve one will considerably augment another fault. It is not within the province of this paper to show what the likely changes would be which should be followed to improve the objective, but I can indicate what some of the results would be which would arise. For instance, if the visual and chemical foci do not coincide, it is evident that the objective is chromatically over or under corrected, and if the objective would otherwise give a good image, the inner or cemented surface would probably be changed; this might very naturally affect the focal length, which in a telescope objective would hardly be noticed. The focus of the lens might easily be doubled before the proper correction would be reached, and then changes would again be necessary to bring the focus to the proper distance, which would again disturb the chromatic correction as well as perhaps the spherical, which latter designates the amount of curvature of the image. Thus a change of one-sixteenth of an inch in the radius of one of the inner surfaces, which would hardly be noticed in an ordinary lens, might lengthen or shorten the focus of the photographic objective several inches. The changes which sometimes occur are often surprising and inexplicable, even to one who is accustomed to them. It may be found that the amount of spherical aberration is so great that no amount of changing will bring it to the proper standard. One means of partially overcoming it would be the decrease in the size of the lenses, which would mean that they will admit less light, and consequently be slower.

The thickness of the lens which causes the distortion must be accurately determined. However, we will assume that the various corrections are finally combined as far as is possible, and the skill of the optician must determine to what extent they will be. It may be possible to combine the spherical and chromatic aberrations sufficiently to make the former acceptable, and a new series of experiments will have to be undertaken based on a combination of new glass.

After a lens which meets the ideal of the optician is completed it may be said, "We can understand that the first lens has involved a great amount of work, but after the completion of the sample none of these difficulties will arise." To a certain extent this is true, but it must be remembered that the optician's work is almost entirely empirical. Each lens is an experiment; there is an individuality in each which cannot be overlooked. A lens is rarely if ever perfect when completed, and each one is a special study. There are certain features which rarely if ever change when working under the same formulas and using the same glass, such as coincidence of visual and chemical foci, centering, and size, but others, such as homogeneity and refrangibility of glass, sphericity of surfaces, length of focus, are variable, and often can only be reached after repeated trials, and in many instances cannot be obtained at all.

There is one point which I have not yet touched, and which is of the utmost importance, and that is the sphericity of surfaces. To simply grind and polish a lens is exceedingly simple; to do so and obtain spherical surfaces is extremely difficult. Instead of being spherical, a surface may be and often consists of a series of elevations and depressions. They may be in the shape of rings, or may be confined to spots or radiate from the center, in which way I have seen them as pronounced as the spokes in a wheel. Heat, even when moderate, when applied to a certain portion of the lens, causes the same effect. There are optical tests by which you can easily see the expansion of glass after the finger has been allowed to rest upon it for a moment. The same effect may be obtained by fixing the lens in the mounting.

I have often examined lenses which were so distorted by the pressure exerted on them in the mounting that it seemed almost impossible that they could form even a fair image. What is the effect when these conditions exist? First of all, there is a lack of sharpness over the plate and then depth of focus. An elevation on the lens will give a shorter focus for all those rays which fall upon it, because of its shorter radius than the focal point for the entire surface; whereas a depression will cause a longer focus, so that instead of all the rays combining in one point there are a series of focal points. When depth of focus is caused by reason of this fault it is to be condemned, because it is at the sacrifice of definition, and any lens possessing it cannot be rated as good. Depth of focus when caused in this manner is one of the qualities which can be determined without comparative tests, and every lens purchased should be tested to this end. A good means to determine the proper correction of the surfaces is by the use of a diaphragm. Focus for a sharp image on the ground glass by means of a magnifier with a full opening of the lens, and note this point in the camera. Then rack out of focus and insert a diaphragm sufficiently large that the image can just be distinguished, and again focus by means of the magnifier. If the objective is perfectly corrected, this point will coincide with the first, and if not, it is, as stated before, a serious fault, because there will be a different focus for each diaphragm.

Depth of focus and speed are incompatible, inasmuch as both qualities depend on the aperture of

* Read at the Minneapolis convention, July, 1888.

lenses, assuming of course a relatively large diaphragm and focal length. While the former decreases with the increase in the aperture, the latter increases. Depth of focus is no doubt a very desirable quality, but to obtain it in a legitimate way with high speed is simply impossible. In two lenses of similar construction of the same diameter and focus it will be exactly similar, and the ratio of depth will increase with the decrease of the diaphragm. In view lenses depth of focus can almost always be obtained by the use of diaphragms, and this is also true in objectives specially made for portraiture, but in these the same is obtained by placing two systems farther apart or varying the distance of the individual lenses, which means nothing more or less than the production of spherical aberration.

The extent of flatness of field and distortion in lenses are variable quantities, and, although depending to a certain extent on the diameter of lenses, exist to a greater or less degree in one or the other lens, according to the amount of skill and care of the optician. The tendency almost since the first use of lenses has been the increase of speed and consequent increase of aperture of lens, and although the advance has been and is slow to the uninitiated, it means an enormous amount of work to the optician. Every degree of increase represents a considerable outlay of mental and manual labor, and can only be maintained by correspondingly greater attention to the minutiæ of work. Each individual reproduction is to him a source of pride, and he works with love and ardor over every step of his work. Outside of this, however, he is fully aware of the detrimental influence of imperfect work, and his ambition is not only to accomplish the highest result, but to maintain it after it has been reached. The actual work of grinding and polishing is comparatively trifling, as is shown in the cheaper form of lenses, where the cost of glass is just as high, but wherein the lenses are used whether good or bad, unless they have faults easily noticed. The time-consuming and worrying work is that of continually testing and correcting the lenses. When we remember that the best, although none too good, involves the amount of work I have endeavored to portray, you will no doubt feel that the optician does not ask too much remuneration for it.

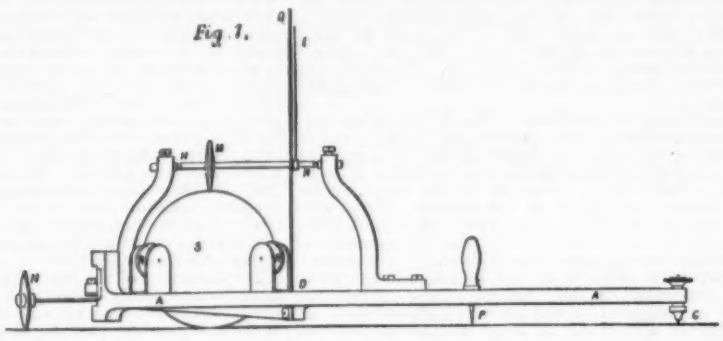
Now as to the homogeneity of glass. A disk should be of the same consistency throughout. When it is not, it possesses either impurities or air bubbles which are usually easily seen, or so-called striæ—which are not so discernible, but of greater importance. These are caused by the unequal consistency of the glass or unequal annealing, and have a similar appearance to a glass of water when strong sugar water is poured into it and is not well mixed, or heated air as it rises from a stove or hot ground. All glass not specially made for optical purposes has them, and can be easily seen by looking through it edgewise, even in the best plate. Of course no disk is used which shows them or air bubbles or impurities on a preliminary examination; they often appear before the lenses are completed and work then ceases, but very often they cannot be detected until the lenses are finished. Air bubbles can easily be seen by any person, and when they exist the optician must judge whether they are sufficient to impair the salability of a lens.

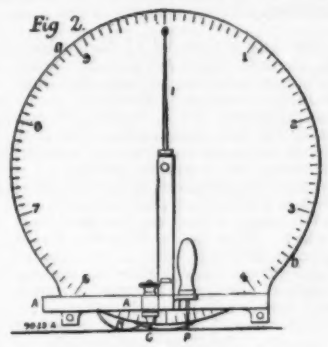
If, however, a man who has a reputation to guard permits it to pass—and I would add that it is as hurtful to his eye as to any person—then the purchaser should not be hasty to condemn it, for it then usually possesses merits which far outweigh this disadvantage. Take for instance an air bubble as large as a pin head in an ordinary size lens. Its area is so infinitesimally small as compared with the area of the lens that it is of no account whatever, and does not affect the lens in the least. Although it may sound strange, I would, for my part, select a lens containing an air bubble in preference to one without it, provided they were from one reliable firm.

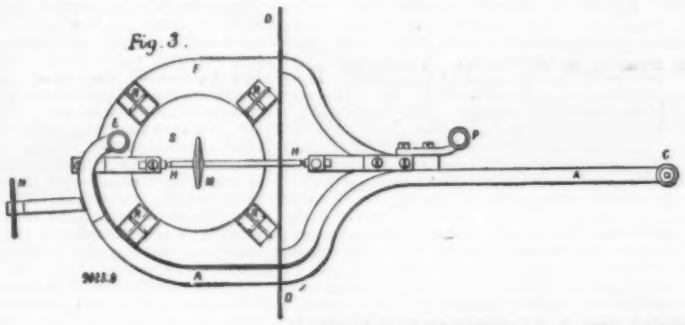
Striæ, however, which are difficult to detect are positively injurious when existing to any extent, inasmuch as they refract the rays passing through them in different directions, thus preventing them from combining to form the image, and they sometimes may cause a false light. They often pervade an entire lens and occasionally can be seen with the naked eye, but as a rule not. An easy method of looking for the most glaring is as follows: Unscrew the systems and examine each separately. Place one in the camera or on the table in an upright position, and back of it at any distance a lamp or gas jet. Look for the focal point by means of a white paper, and get the eye in the same position, which can be easily done after a little practice. The lens will be found brilliantly illuminated and the striæ will stand out as dark shadows. When a few small knife edge threads show, they are of little moment, but when in a circle of light there is a wavy appearance it is generally indicative of other striæ which are injurious, but cannot be determined in this manner.

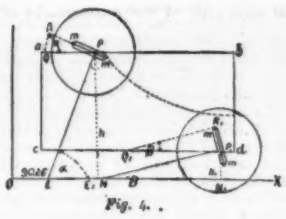
I have shown how some of the faults may be determined by almost any person, but others, such as definition, distortion, and amount of speed, can only be judged by a comparative test or by a person of wide experience. Comparing a lens with one of known excellence is the only reliable manner, but then the following points, among which I recapitulate those already mentioned, should be observed. Determine coincidence of visual and chemical foci. Determine coincidence of ground glass and plate in plateholder. Use flat plates when ground glass is flat; if this is not flat, use plates corresponding with it. Determine spherical correction by means of diaphragms.

The two lenses should be for the same size plate, and of about the same aperture and focus. Lenses should always be tested first with full aperture or large stops of the size, as small stops correct spherical aberration in good lenses as well as poor ones. If desired, they can be done with small stops later on. Make comparisons under the same conditions of light. For spherical aberration and distortion focus on printed matter or on a map fastened to a screen, and have the lens square with the objective and within two or three times the equivalent focus of the lenses, as they are then under the most strained conditions. For depth of focus use stationary objects which have thickness, or a view. Always focus the lens on the same point, and never make a comparison without the use of a magnifying glass for focusing as well as for examining the negatives. Last, but most important, make the comparison in the spirit of arriving at the truth, and do not permit your judgment to be biased or influenced by your feelings.









A NEW SPHERICAL PLANIMETER.

A NEW PLANIMETER.

ON A NEW SPHERE PLANIMETER.*

By Prof. HELE SHAW, M. Inst. C. E.

THE want has long been felt of some instrument for measuring areas which, while possessing the accuracy of the Amsler planimeter, would have the great advantage of giving a reading by means of a pointer moving over a dial face of such magnitude as to obviate the use of a vernier. The author, four years ago, brought forward a class of sphere integrator under the name of sphere and roller mechanism, in which, by employing the rolling of two surfaces in contact with each other instead of the combined slipping and rolling of the Amsler type of instrument, a satisfactory solution of the problem appeared to have been attained. Various forms of these integrators were thoroughly tested, but with unsatisfactory results, inasmuch as they always gave a slight error of variable amount, and it has since been found by means of specially designed experiments that the universally accepted principle of rolling contact relied upon in their design did not hold in practice under the particular conditions in which it was there applied. The sphere planimeter, which is now exhibited for the first time, really belongs to the Amsler class of integrator, though resembling in external appearance the author's previous instrument above referred to, since one essential feature of it is a sphere.

The instrument consists of a bent bar, A A, one end of which forms the fixed center, C, upon the surface containing the area to be measured. The other end is jointed at E to a frame, F, which guides a sphere, S, by means of four rollers, R R R R, the centers of these rollers being carried upon small rigid brackets. The frame which supports the dial, D D, is continued by means of a bar, at the end of which is pointer, P, which is passed round the perimeter of the figure to be integrated. Upon the sphere rests a small measuring roller or integrating wheel, M, the axis, H H, of which carries the recording index, I, and a pinion, K.

This pinion gears with a wheel ten times as large, working on the back of the dial, by means of which higher readings are recorded. Undue pressure between the measuring roller and the sphere is prevented by means of the roller, N, which is attached to the bar, A A.

The theory of action may be thus explained: Suppose the area of a rectangular figure, a, b, c, d (Fig. 4) to be required, and suppose first that instead of the pointer, P, moving over the perimeter, the sphere itself is rolled along it, also that instead of the center of the joint, E, moving in the arc of a circle, as it would do in the actual instrument, it moves along the line, O X. As the sphere passes over the figure it transmits an exactly similar motion, but in the reverse direction, to the roller, m m, resting upon it as the roller would receive if moving in contact with the surface of the paper. The roller thus slips as well as turns, the relative value of the two effects depending respectively upon the ratio of the two sides R Q : R P of the triangle, P Q R. These values are the absolute quantities for a movement, P Q, of the center of the sphere, P. Thus in moving a distance, P Q, along the line a b, the turning of the roller $=$P R$=$P Q sin $<$ R P Q. Similarly for a movement along c d, the turning depends upon the sine of the angle of inclination of the roller. Draw perpendiculars, P N, P_1 N_1, to the line, O X, from the center of the sphere, and let

$$h = P\,N$$
$$h_1 = P_1 N_1.$$

Let the angles made by the center line, E P, with line, O X, be respectively α and β. Then since the triangles P Q R and P E N are similar, and also the triangles, P_1 Q_1 R, and P_1 E, N_1,

$$< P\,E\,N = < R\,P\,Q = \alpha$$
$$< P_1\,E,\,N_1 = < R,\,P_1\,Q_1 = \beta.$$

Then for a movement of P along the line, a b,

Turning of roller$=a\,b \sin \alpha$,

and for a movement along c d, the direction of motion being now reversed,

Turning of roller$=c\,d \sin \beta$.

In moving down the side, a c, the motion of the roller is equal and opposite to that which it has in moving up the side, d b. Therefore, finally,

Total turning of roller$=a\,b \sin \alpha - c\,d \sin \beta$.
$=a\,b\,(\sin \alpha - \sin \beta)$
l=length of center line, E P
If $h = l \sin \alpha$
$h_1 = l \sin \beta$.

$$\text{Turning of roller} \quad a\,b\,(h - h_1) \times \frac{1}{l}$$
$$= a\,b \times c\,d \times \frac{1}{l}$$
$$= \text{area of figure} \times \text{constant}.$$

Using a suitable scale, the area of the figure is therefore shown by the reading on the dial.

Now it is clear (1) that so long as the pointer moves over the figure the sphere may be moved to any part of the bar without affecting the result; (2) that so long as the pointer returns to the initial position, the end, E, need not move along a straight line, but may travel in the arc of a circle; (3) that the reasoning applies to any form of figure, such as the indicator diagram shown in dotted lines, the area of which would be correctly given by passing the pointer round its perimeter.

It may be remarked that the action of the sphere is simply to transmit the motion of the roller, and therefore so long as no slipping takes place on the surface of the paper beneath, the record is given with the same degree of accuracy as with the Amsler planimeter, but with the important advantage of a large dial reading, there being only the simple difference that the pointer must in the sphere planimeter be moved in the opposite direction round the perimeter of the figure to be measured.

One feature of interest in the instrument is the use of the four guiding rollers, R R R R, which are in contact with the great circle of the sphere formed by the intersection of the horizontal plane through its center, and thus allow the sphere to turn without resistance in any direction. To this end the rollers are carried in rigid

* Read before Section G of the British Association, at Bath.—*Engineering.*

brackets and do not exert any pressure upon the sphere, but just keep it in position in the frame. They are pivoted on very fine centers, and they are of steel with polished edges, so that even when the sphere is moving in a direction causing its axis of rotation to pass through one of these edges, the motion of the sphere is not appreciably retarded by frictional resistance. Hence the planimeter is found to be correct up to the limit of accuracy to which records can be read on the dial face.

[Continued from SUPPLEMENT, No. 669, p. 10690.]

THE HISTORY OF A SCIENTIFIC DOCTRINE.*

By S. P. LANGLEY.

A MARKED step is taken about 1811 by a young Frenchman, De la Roche, who deserves to be better remembered than he is, for he clearly anticipated some of Melloni's discoveries. De la Roche in particular shows that, of two successive screens, the second absorbs heat in a less ratio than the first: whence he, before any one else, I believe, derives the just and most important, as well as the then most novel, conception that radiant heat is of different kinds. He sees, also, that as a body is heated more and more, there is a gradual and continual advance, not only in the amount of heat it sends out, but in the kind, so that, as the temperature still rises, the radiant heat becomes light by imperceptible gradations; and he concludes that heat and light are due to one simple agent, which, as the temperature rises yet more, appears more and more as light, or which, as the luminous radiation is absorbed, reappears as heat. Very little of it, he observes, passes even transparent screens at low temperatures, but more and more does so as the temperature rises.

All this is a truism in 1888, but it is admirably new as well as true in 1811; and if De la Roche had not been removed by an early death, his would have not improbably been the greatest name of the century in the history of our subject—an honor, however, which was in fact reserved for another.

The idea of the identity of light and radiant heat had by this time made such progress that the attempt to polarize the latter was made in 1818 by Berard. We have just seen in Herschel's case how the most sound experiment may lead to a wrong conclusion, if it controverts the popular view. We now have the converse of this in the fact that the zeal of those who are really in the right way may lead to unsound and inconclusive experiment; for Berard experimentally established, as it was supposed, the fact that obscure radiant heat can be polarized. So it can, but not with such means as Berard possessed, and it was not till a dozen years more that Forbes actually proved it.

At this time, however fairly we seem embarked on the paths of study which are followed to-day, and while the movement of the main body of workers is in the right direction, it is yet instructive to observe how eminent men are still spending great and conscientious labor, their object in which is to advance the cause, while the effect of it is to undo the little which has been rightly done, and to mislead those who have begun to go right.

As an instance both of this and of the superiority of modern apparatus, we may remark, after having noticed that the ability of obscure heat to pass through glass, if completely established, would be a strong argument in favor of its kinship to light, and that De la Roche and others had indicated that it would do so (in which we now know that they were right)—that at this stage, or about 1816, Sir David Brewster, the eminent physicist, made a series of experiments which showed that it would not so pass. Ten years later, in view of the importance of the theoretical conclusion, Baden Powell repeated his observations with great care, and confirmed them, announcing that the earlier experimenters were wrong, and that Brewster was right.

Here all these years of conscientious work resulted in establishing, so far as it could be established, a wholly wrong conclusion in place of a right one already gained. It may be added that, with our present apparatus, the passage of obscure radiant heat through glass could be made convincingly evident in an experiment which need not last a single second.

We are now arrived at a time when the modern era begins; and in looking back over one hundred and fifty years, from the point of view of the experimenter himself, with his own statement of the truth as he saw it, we find that the comparison of the progress of science to that of an army, which moves perhaps with the loss of occasional men, but on the whole victoriously and in one direction, is singularly misleading; and I state this more confidently here, because there are many in this audience who did not get their knowledge of nature from books only, but who have searched for the truth themselves; and, speaking to them, may I not say that those who have so searched know that the most honest purpose and the most patient striving have not been guarantees against mistakes—mistakes which were probably hailed at the time as successes? It was some one of the fraternity of seekers, I am sure, who said, "Show me the investigator who has never made a mistake, and I will show you one who has never made a discovery."

We have seen the whole scientific body, as regards this particular science of radiant energy, moving in a mass in a wrong direction, for a century; we have seen that individuals in it go on their independent paths of error; and we can only wonder that an era should have come in which such a real advance is made as in ours.

That era has been brought in by the works of many, but more than by any other through the fact that in the year 1801 there came into the world at Parma an infant who was born a physicist, as another is born a poet; nay, more; who was born, one might say, a devotee of one department of physics—that of radiant heat; being affected in his tenderest years with such a kind of precocious passion for the subject as the childish Mozart showed for music. He was ready to sacrifice everything for it; he struggled through untold difficulties, not for the sake of glory or worldly profit, but for radiant heat's sake; and when fame finally came to him, and he had the right to speak of himself, he wrote a preface to his collected researches which is as remarkable as anything in his works. In this preface he has given us, not a summary of previous memoirs on the subject, not a table of useful factors and formulæ, not anything at all that an English or American scientific treatise usually begins with, but the ingenuous story of his first love, of his boyish passion for this beloved mistress; and all this with a trust in us his readers which is beautiful in its childlike confidence in our sympathy.

I must abbreviate and injure in order to quote; but did ever a learned physical treatise and collection of useful tables begin like this before?

"I was born at Parma, and when I got a holiday used to go into the country the night before and go to bed early, so as to get up before the dawn. Then I used to steal silently out of the house, and run, with bounding heart, till I got to the top of a little hill, where I used to set myself so as to look toward the east." There, he tells us, he used, in the stillness of nature, to wait the rising sun, and feel his attention rapt less with the glorious spectacle of the morning light itself than with the sense of the mysterious heat which accompanied its beams, and brought something more necessary to our life and that of all nature than the light itself.

The idea that not only mankind, but nature, would perish though the light continued, if this was divorced from heat, made a profound impression, he tells us, on his childish mind.

The statement that such an idea could enter with dominating force into the mind of a child will perhaps seem improbable to most. It will, however, be comprehensible enough to some here, I have no doubt.

Is there some ornithologist present who remembers a quite infantile attraction which birds possessed for him above all the rest of the animated creation; some chemist whose earliest recollections are of the strange and quite abnormal interest he found as a child in making experimental mixtures of every kind of accessible household fluid and solid; some astronomer who remembers when a very little creature that not only the sight of stars, but of any work on astronomy, even if utterly beyond his childish comprehension, had an incomprehensible attraction for him?

I will not add to the list. There are, at any rate, many here who will understand and believe Melloni when he tells how this radiant heat, commonplace to others, was wonderful to his childish thought, and wrought a charm on it such that he could not see wood burn in a fireplace or look at a hot stove without its drawing his mind, not to the fire or iron itself, but to the mysterious effluence which it sent.

This was the youth of genius; but let not any fancy that genius in research is to be argued from such premonitions alone, unless it can add to them that other qualification of genius which has caused it to be named the faculty of taking infinite pains. Melloni's subsequent labors justified this last definition also; but I cannot speak of them here further than to say that after going over a large part of his work myself, with modern methods and with better apparatus, he seems to me the man, of all great students of our subject, who, in reference to what he accomplished, made the fewest mistakes.

Melloni is very great as an experimenter, and owes much of his success to the use of the newly invented thermopile, which is partly his own. I can here, however, speak only of his results, and of but two of these—one generally known; the other, and the more important, singularly little known, at least in connection with him.

The first is the full recognition of the fact, partly anticipated by De la Roche, that radiant heat is of different kinds, that the invisible emanations differ among themselves just as those of light do. Melloni not only established the fact, but invented a felicitous term for it, which did a great deal to stamp it on recognition—the term "thermochrose," or heat-color, which helps us to remember that, as the visible and apparently simple emanation of light is found to have its colors, so radiant heat, the invisible but apparently simple emanation, has what would be colors to an eye that could see them. This result is well known in connection with Melloni.

The other and the greater, which is not generally known as Melloni's, is the generalization that heat and light are effects of one and the same thing, and merely different manifestations of it. I translate this important statement as closely as possible from his own words. They are that:

"*Light is merely a series of caloriſic indications sensible to the organs of sight or, Vice Versa, the radiations of obscure heat are veritable* INVISIBLE RADIATIONS *of light.*"

The italics and the capitals are Melloni's own.

He wishes to have no ambiguity about his announcement behind which he may take shelter; and he had so firm a grasp of the great principle that, when his first attempts to observe the heat of the moon failed, he persevered, because this principle assured him that where there was light there must be heat. This statement was made in 1843, and ought, I think, to insure to Melloni the honor of being first to distinctly announce this great principle.

The announcement passed apparently unnoticed, in spite of his acknowledged authority; and the general belief not merely in different entities in the spectrum, but in a material caloric, continued as strong as ever. If you want to see what a hold on life error has, and how hard it dies, turn to the article "Heat" in the eighth edition of the "Encyclopædia Britannica," where you will find the old doctrine of caloric still in possession of the field in 1853; and still later, in the generally excellent "English Encyclopædia" (edition of 1867), the doctrine of caloric is, on the whole, preferred to the undulatory hypothesis. It is very probable that a searcher might find many traces of it yet lingering among us; so that Giant Caloric is not, perhaps, even yet quite dead, though certainly grown so crazy, and stiff in the joints, that he can now harm pilgrims no more.

So far as I know, no physicist of eminence reasserted Melloni's principle till J. W. Draper, in 1872. Only sixteen years ago, or in 1872, it was almost universally believed that there were three different entities in the spectrum, represented by actinic, luminous, and thermal rays.

Draper remarks that a ray consists solely of ethereal vibrations whose lost *vis viva* may produce either heat or chemical change. He uses Descartes' analogy of the vibration of the air and sound; but he makes no mention either of Descartes or of Melloni, and speaks of the principle as leading to a modification of views then "universally" held. Since that time the theory has made such rapid progress that, though some of the older men in England and on the European continent have not welcomed it, its adoption among all physicists of note may be said to be now universal, and a new era in our history begins with it. I mean by the recognition that there is one radiant energy which appears to us as "actinic," or "luminous," or "thermal" radiation, according to the way we observe it. Heat and light, then, are not things in themselves, but whether different sensations in our own bodies, or different effects in other bodies, are merely effects of this mysterious thing we call radiant energy, without doing more in this than give a name to the ignorance which still hangs over the ultimate cause.

I am coming down dangerously near our own time—dangerously for one who would be impartial in dealing with names of those living and with controversies still burning. In such a brief review of this century's study of radiant energy in other forms than light, it has been necessary to pass without mention the labors of such men as Pouillot and Becquerel in France, of Tyndall in England, and of Henry in America. It has been necessary to omit all mention of those who have advanced the knowledge of radiant energy as light, or I should have had to speak of labors so diverse as those of Fraunhofer, of Kirchoff, of Fresnel, of Stokes, of Lockyer, and many more. I have made no mention, in the instructive history of error, of many celebrated experimental researches; in particular of such a problem as the measurement of solar heat, great in importance, but apparently most simple in solution, yet which has now been carried on from generation to generation, each experimenter materially altering the result of his predecessor, and where our successors will probably correct our own results in time. I have not spoken of certain purely experimental investigations, like those of Dulong and Petit, which have involved immense and conscientious labor, and have apparently rightly earned the name of "classic" from one generation, only to be recognized by the next as leading to wholly untrustworthy results, and leaving the work to be done again with new methods, guided by new principles.

In these instances, painstaking experiments have proved insufficient, less from want of skill in the investigator than from his ignorance of principles not established in time to enable him to interpret his experiments; but, if there were opportunity, it would be profitable to show how inexplicably sometimes error flourishes, grows, and maintains an apparently healthy appearance of truth, without having any root whatever. Perhaps I may cite one instance of this last from my own experience.

About fifteen years ago it was generally believed that the earth's atmosphere acted exactly the part of the glass in a hotbed, and that it kept the planet warm by exerting a specially powerful absorption on the infrared rays.

I had been trained in the orthodox scientific church, of which I am happy to be still a member; but I had acquired perhaps an almost undue respect, not only for her dogmas, but for her least sayings. Accordingly, when my own experiments did not agree with the received statement, I concluded that my experiments must be wrong, and made them all over again, till spring, summer, autumn, and winter had passed, each season giving its own testimony; and this for successive years. The final conclusion was irresistible, that the universal statement of this alleged well known fact (inexplicable as this might seem, in so simple a matter) was directly contradicted by experiment.

I had some natural curiosity to find how every one knew this to be a fact; but search only showed the same statement (that the earth's atmosphere absorbed dark heat like glass) repeated everywhere, with absolutely nowhere any observation or evidence whatever to prove it, but each writer quoting from an earlier one, till I was almost ready to believe it a dogma superior to reason and resting on the well-known "*Quod semper, quod ubique, quod ab omnibus, creditum est.*"

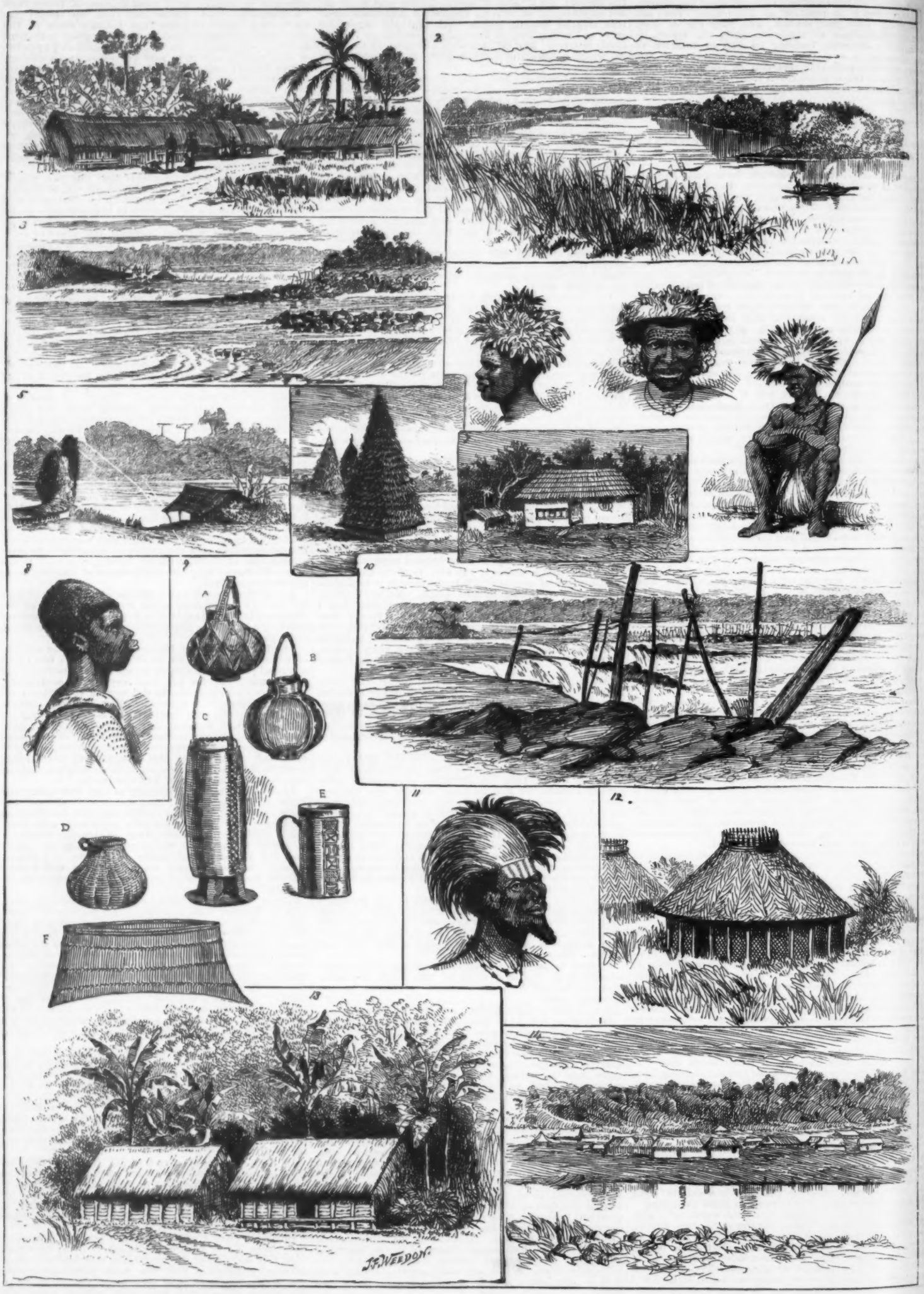
Finally, I appear to have found its source in the writings of Fourier, who, alluding to De Saussure's experiments (which showed that dark heat passed with comparative difficulty through glass), observes that if the earth's atmosphere were solid, it would act as the glass does. Fourier simply takes this (in which he is wholly wrong) for granted; but as he is an authority on the theory of heat, his words are repeated without criticism, first by Poisson, then by others, and then in the text books; and, the statement gaining weight by age, it comes to be believed absolutely, on no evidence whatever, for the next sixty years, that our atmosphere is a powerful absorber of precisely those rays which it most freely transmits.

The question of fact here, though important, is, I think, quite secondary to the query it raises as to the possible unsuspected influence of mere tradition in science, when we do not recognize it as such. Now, the Roman Church is doubtless quite logical in believing in tradition, if these are recommended to the faithful by an infallible guide; but are we, who have no infallible guide, quite safe in believing all we do, with our fond persuasion that in the scientific body mere tradition has no weight?

In even this brief sketch of the growth of the doctrine of radiant energy, we have perhaps seen that the history of the progress of this department of science is little else than a chapter in that larger history of human error which is still to be written, and which, it is safe to say, would include illustrations from other branches of science as well as my own.

But—and here I ask pardon if I speak of myself—I have been led to review the labors of other searchers from this standpoint, because I had first learned out of personal experience that the most painstaking care was no guarantee of final accuracy; that to labor in the search for a truth with such endless pains as a man might bestow if his own salvation were in question did not necessarily bring the truth; and because, seeking to see whether this were the lot of other and greater men, I have found that it was, and that, though no one was altogether forsaken of the truth he sought (or on the whole review of his life as a seeker, but might believe he had advanced her cause), yet there was no criterion by which it could be told at the time whether, when after long waiting there came in view what seemed once more her beautiful face, it might not prove, after all, the mockery of error; and probably the ap-

* Address before the American Association for the Advancement of Science, at Cleveland, O., Aug. 15, 1888, by Professor S. P. Langley, the retiring president of the association.



1. Bolobo, on the Congo River.
2. Looking up the Congo from the house of Shiek Mahomed-bin-Seid, at Stanley Falls.
3. View from below Stanley Falls.
4. The Babulu-Wasongolo Tribe (Three Types).
5. Village in Mahomed-bin-Seid's District.
6. Huts at Yambina.
7. Our House at Stanley Falls.
8. Native Woman of Aruwimi Falls.
9. A and B. Palm-oil Pots: Yambina.
   C. Pot containing Cam-wood and Olives, Articles of an Aruwimi Native's Toilet; carried over the shoulder.
   D. Basket used for sifting Manioc Flour, &c.
   E. Bark-box used for preserving Manioc Flour, &c.
   F. Basket for Provisions.
10. Stanley Falls.
11. Native of the Aruwimi Country.
12. Houses in rows: Five hours' march to Stanley Falls.
13. Itimbo.
14. Houses of Tippoo Tib, Stanley Falls.

THE EMIN PASHA RELIEF EXPEDITION IN CENTRAL AFRICA.—SKETCHES BY MR. HERBERT WARD, A COMPANION OF MR. H. M. STANLEY.

peal might be made to the experience of many investigators here with the question, "Is it not so?"

What then? Shall we admit that truth is only to be surely found under the guidance of an infallible church? If there be such a church, yes! Let us, however, remember that the church of science is not such a one, and be ready to face all the consequences of the knowledge that her truths are put forward by her as provisional only, and that her most faithful children are welcome to disprove them.

What then, again? Shall we say that the knowledge of truth is not advancing? It is advancing, and never so fast as to-day; but the steps of its advance are set on past errors, and the new truths become such stepping stones in turn.

To say that what are truths to one generation are errors to the next, or that truth and error are but different aspects of the same thing to our poor human nature, may be to utter truisms; but truisms which one has verified for one's self out of a personal experience are apt to have a special value to the owner; and these lead, at any rate, to the natural question, "Where is, then, the evidence that we are advancing in reality, and not in our own imagination?"

There are many here who will no doubt heartily subscribe to the belief that there is no absolute criterion of truth for the individual, and admit that there is no positive guarantee that we, with this whole generation of scientific men, may not, like our predecessors, at times go the wrong way in a body, yet who believe as certainly that science as a whole, and this branch of it in particular, is advancing with hitherto unknown rapidity. In asking to be included in this number, let me add that to me the criterion of this advance is not in any ratiocination, not in any *a priori* truth, still less in the dictum of any authority, but in the undoubted observation that our doctrine of radiant energy is reaching out over nature in every direction, and proving itself by the fact that through its aid nature obeys us more and more, proving itself by such material evidence as is found in the practical applications of the doctrine, in the triumphs of modern photography, in the electric lights in our streets, and in a thousand ways which I will not pause to enumerate.

And here I might end, hoping that there may be some lessons for us in the history of what has been said. I will venture to ask the attention to one more, perhaps a minor one, but of a practical character. It is that in these days, when the advantage of organization is so fully recognized, when there is a well founded hope that by co-operation among scientific men knowledge may be more rapidly increased, and when in the great scientific departments of government and elsewhere there is a tendency to the formation of the divisions of a sort of scientific army—a tendency which may be most beneficially guided—that at such a time we should yet remember that, however rapidly science changes, human nature remains much the same; and (while we are uttering truisms) let us venture to say that there is a very great deal of this human nature even in the scientific man, whose best type is one nearly as unchanging as this nature itself, and one which cannot always advantageously be remodeled into a piece of even the most refined bureaucratic mechanism, but will work effectively only in certain ways, and not always at the word of command, nor always best in regiments, nor always best even under the best of discipline.

Finally, if I were asked what I thought were the next great steps to be taken in the study of radiant heat, I should feel unwilling to attempt to look more than a very little way in advance. Immediately before us, however, there is one great problem waiting solution. I mean the relation between temperature and radiation; for we know almost nothing of this, where knowledge would give new insight into almost every operation of nature, nearly every one of which is accompanied by the radiation or reception of heat, and would enable us to answer inquiries now put to physicists in vain by every department of science, from that of the naturalist as to the enigma of the brief radiation of the glow worm to that of the geologist who asks as to the number of million years required for the cooling of a world.

When, however, we begin to go beyond the points which seem, like this, to invite our very next steps in advance, we cannot venture to prophesy, and must content ourselves with the knowledge that through our study man is beginning to apprehend the full meaning of one of the early great ones in science, who described him as the meeting point of two infinities.

That there is an infinite of space above him, he has long known; but that there is another absolute infinity and the possibilities which lie in the study of the infinitesimals of space below him, he is only beginning to realize. The secular movements, whose accomplishment demands more than a million years of time, he has already considered; but of the possibilities which lie in the study of actions whose whole duration is far less than the millionth of a second, he has hardly even yet begun to think; and these are but a part of the ungarnered fields of research which open to the student of that radient energy which sustains, with our own being, that of all animated nature, of which humanity is but a part. If there be any students of nature here, who, feeling drawn to labor in this great field of hers, still doubt whether there is yet room, surely it may be said to them, "Yes; just as much room as ever, as much room as the whole earth offered to the first man;" for that field is simply unbounded, and everything that has been done in the past is, I believe, as nothing to what remains before us.

The days of hardest trial and incessant, bewildering error in which your elders have wrought seem over. You "in happier ages born," you of the younger and the coming race, who have a mind to enter in and possess it, may, as the last word here, be bidden to indulge in an equally unbounded hope.

THE EMIN PASHA RELIEF EXPEDITION.

MR. JOSEPH HATTON writes as follows to the *Illustrated London News*:

Readers of the articles which have from time to time appeared under the above heading in the *Illustrated London News* will have been more or less prepared for startling incidents in the history of the Emin Bey expedition. The serious difficulties that threatened the advance have been dwelt upon, but with caution—my correspondent being under articles of agreement with Mr. Stanley which neither he nor I would willingly disregard. Mr. Ward has forwarded to me sketches and notes, portions of which I am privileged to publish in these columns, the object being rather to illustrate some of the country through which the expedition has passed than to offer any special references to its policy or management. The fatal disaster which has befallen Major Barttelot is by many regarded as indicative of the previous death of Stanley; but the fact of the news of poor Barttelot's assassination traveling home so quickly is rather encouraging than otherwise as touching the fate of the famous journalistic explorer. "Ill news travels apace," even in Africa; and as long as there is no definite intelligence of the death of Stanley, so long may we continue to have not only good hope of his welfare, but of the ultimate success of his expedition. Stanley's career is the best answer to the various rumors and reports of his intentions in Central Africa. The latest announcement is that he went out to found a new empire, and intended to proclaim himself emperor. A New York correspondent says Stanley offered him a position as one of his ministers. Mr. Stanley had probably been amusing himself in this romantic suggestion. Those who saw him last on this side of the Atlantic, and who are associated with him in his arduous work, know well enough that his mission was the relief of Emin Bey; and if he has gone out of the prescribed route, it is under the pressure of circumstances over which he has had no control.

The accompanying illustrations are from drawings by my Congo correspondent, Mr. Ward, made principally at Stanley Falls and in the neighborhood of the Aruwimi camp, so often mentioned of late in connection with the expedition, and which Major Barttelot broke up to follow his chief. Bolobo, which forms one of our first illustrations, has been mentioned in former notes. Its history is more or less tragic. In connection with the present expedition it has, however, a pacific and uneventful record. It is the great center of the ivory and cam-wood powder trade. The native merchants do their business through agents at Stanley Pool. Bolobo, during Mr. Stanley's experience of it, had been twice at war and twice burned to the ground. Eventually, peace was established all round, and the station has become more or less safe; but to secure outposts of this importance, they ought to be efficiently garrisoned. In a district where, as Stanley confesses, the most trivial incidents will bring on a battle, an efficient garrison is needed at all times. The Bolobo country commences with the picturesque little village of Itimba, the tropical prettiness of which is artistically suggested in Mr. Ward's sketch. It is situated on a low hill, thickly wooded. "Then, as you sail up the river," says Mr. Stanley, "village after village appears, in a nearly continuous line, for about an hour, when the station (Bolobo) comes into view on the open higher ground behind the narrow belt of tall timber lining the river side." The station is healthy; and some day, when Europeans have learnt the diplomatic art of managing the natives, the district may develop into a fine agricultural settlement. "Imagine a strip of the left bank of the river, about twelve miles long, a thin line of large umbrageous trees close to the water's edge, and a gently sloping background of cleared country rising to about thirty feet above the tallest tree. Just above the center of this strip, on the open ground, is the station of Bolobo, consisting of a long mat-walled shed, a mud and wattle kitchen, a mud-walled magazine with grass roofs, and about seventy huts arranged in a square, on the outside of the inner group of buildings. Above and below it, close to the water side, amid banana and palm groves, are sheltered about fifteen villages. Eight of these—Itimba, Mimgolo, Biangulu, Ururu, Mongo, Mangu, Yambula, and Lingenji—are below the station. Eight are above, among which is Mbanga and a few villages of the Banunu tribe. These form what is called Bolobo."

It is hardly necessary to describe Stanley Falls and the river scenery. But the accompanying fresh illustrations of the locality are interesting. The drawings were made in the autumn of 1887. They are quite in keeping with the eloquent accounts we have had of the two main channels of the river that are almost bridged at the falls. The stakes and nets in the illustrations below the falls are familiar objects of the river, and mark the various cataracts. Most of the local tribes are fishermen: the tremendous operations of the Wenya people have been graphically chronicled by Mr. Stanley, not the least interesting of whose latter chapters of "The Congo Free State" is the history of Tippoo Tib's cunning dealings with the hardy Wenya men, whereby he was enabled to navigate the river and establish himself at Stanley Falls. The house of Tippoo Tib is from a drawing made from the site of the Stanley Falls station, Aug. 30, 1887. In the illustration of Mr. Ward's house at the falls we have a suggestion of "home" in the construction of the high doorway and ample windows; and on the walls, I glean from his letters, were photographs of friends and reminiscences of the *Illustrated London News*. Tippoo Tib's personality, his wives and retinue, have been previously noted in these papers. Mr. Ward in one of his letters mentions, as a great surprise and a stroke of genius, Stanley's treaty with Tippoo Tib, whose aid he regarded as absolutely necessary to a successful issue of the expedition at Wadelai. The difficulties of Stanley and his officers are possibly in some cases nevertheless increased by their alliance with the Arabs, who have left behind them on all hands rancorous memories among the natives of nearly every class.

IRISH FLAX CULTURE—FLAX RIPPLERS AT WORK.

IRISH FLAX CULTURE.

By H. MONIE, Jr.

THE flax plant has been cultivated in Ireland and its filaments spun and woven into cloth from time immemorial, but no authentic record of its first introduction is at the present time in existence. Up to the beginning of the present century the methods of cultivation and the manufacturing appliances were of the most rude and simple construction, little in fact removed from those in favor with the ancient Egyptians; and it was not until a few years later, when the genius of English and Scotch machinists was directed to the backward condition of the industry, that the manufacture sprang into active life, and the basis of its present important position was successfully laid. At the present time, even no other industry requires so much manual labor as that of flax, and consequently we may reasonably suppose that the future will see considerable alterations in the systems of manufacture and the substitution in many departments of labor-saving mechanical appliances. During the past few years the annual average area placed under the flax crop was 127,000 acres, the produce of which amounted to 22,000 tons, made up as follows by the four provinces:

	Tons.
Ulster	21,700
Leinster	200
Connaught	50
Munster	50

As the Irish flax manufacturers alone consume 36,000 tons and the export trade amounts to 4,000 tons, there is thus a deficiency of 18,000 tons, which would require the cultivation of 100,000 more acres to supply. In addition to this, England and Scotland combined consume annually 46,000 tons of flax, so that it will be seen there is ample scope for a great extension of flax culture. £2,000,000 worth of foreign-grown flax is annually imported into this country, a considerable portion of which might, were greater enterprise shown, be retained among us, and go to the support of our own agricultural classes. Another important matter worthy of serious consideration is the fact that the life of our extensive linen manufactures depends almost entirely on the supply from Russia, and we might also include that of Belgium. Should these fail, either from war with that country or a recourse to arms among other great European powers (both of which are not very improbable), it will be easy to understand the danger which exists to and the ruin which would follow among the capitalists of this country; trade would become paralyzed, commercial confidence would cease, and thousands of workpeople brought to poverty and absolute destitution.

The culture of flax, if carried out under proper conditions, can be rendered very profitable, in fact, much more so than any of our cereal crops; and if capital were forthcoming, especially in Ireland, for this object, and for the construction of improved scutch mills and

machinery at different parts of the country, greater profits might easily be realized. The flax plant can be grown on almost any soil; but, of course, the quality is more or less affected thereby. The best is a deep, sound loam, thoroughly well drained and subsoiled. As the plant is a most exhaustive one, however, it should not be grown oftener on the same ground than once in five or seven years, otherwise the yield will be found to be small and unsatisfactory. The following rotation of crops is generally recommended: (1) grass, (2) oats, (3) potatoes, (4) wheat, (5) flax, (6) hay. After the lands are thoroughly well plowed up and the harrowing finished, it is necessary to carefully roll it, so that an even surface may be obtained, otherwise there would be considerable variation in the length of the stalks—an objection which should be avoided as much as possible. The seed is sown broadcast early in April, and this operation should only be entrusted to those who have a thorough knowledge of the crop and an interest in the result of the harvest. To have portions of the land sparsely covered and others too thickly covered will cause much irregularity and reduce its commercial value. The best seeds to use are the Riga and Dutch, the former being especially suitable for all soils and the production of large crops, and the latter for the growth of a finer fiber but of less bulk. Seed for sowing purposes requires almost to be grown specially, and in so doing the following points must be attended to: (1) The plants must have sufficient space to allow of their branching out, and (2) the stalks must not be pulled until the seeds in the bolls become ripe. Where excellency of fiber is required, and the seeds are only to be used for the manufacture of linseed oil and for feeding purposes, the sowing must be thick, as in this way the stems grow tall and straight. Pulling should also begin before the seeds are fully matured, the best time being during the course of changing from the green to the light brown color, and before the stalk has become entirely yellow. This, however, must be determined more or less according to circumstances, and by practical experience. If the flax is pulled too soon, an excess of waste at the hackling and scutching operations will be the result; and if too late, the fiber will be coarse and harsh, while its adhesive elasticity will have become impaired. The quantities of seed which have been found sufficient in well managed farms for sowing purposes are as follows:

	Imperial bushels.
Irish, or plantation acre	3½
Scotch, or Cunninghame acre	2¼
English, or statute acre	2

During the growth of the plants, little attention is necessary beyond that of weeding, and this should be completed before the stalks exceed a height of five or six inches. The women who perform this operation should work facing the wind, so that the plants may be assisted in regaining their upright position when the work is finished. When the harvest time has come, the plants are pulled in handfuls according to their lengths, and these are then laid across each other diagonally until a sheaf is complete, the whole being then carefully bound together. These sheaves are next taken to the ripplers, who separate the seed bolls and seed from the stalks. On many farms rippling is entirely neglected, the sheaves, as pulled, being removed directly to the "steep pit;" but as the seed can be used for many purposes, and the product of an acre may realize from £2 10s. to £3, there is in this way much unnecessary loss to the grower. The best ripplers are of very simple construction, consisting of a block of wood, in which are vertically fixed a series of iron spikes about 18 in. long, made of half inch square iron, placed ½ in. apart at the bottom, and tapering slightly toward the apex. This comparatively great length and smallness of the iron allows it to spring slightly, and so yields to the pull of the stalks instead of presenting a rigid surface, which would act too roughly upon them. This, then, constitutes the "ripple," and when in use it is securely fastened transversely on a plank supported at both ends as shown in the illustration. The ripplers, it will be observed, sit astride the plank on both sides of the ripple, while they operate upon the stalks in the following manner: Taking up a handful of flax from the sheaf at his right hand side, and holding the stalks by the root ends, the rippler spreads the tops out in a somewhat similar manner to a fan, and then draws them rapidly through between the spikes. The bulbs being greater in diameter than the distance apart of the rods, they are therefore stripped off and fall upon a sheet spread on the ground under the plank for the purpose of receiving them. As each handful is rippled it is deposited on the ground at his left hand side, the one being placed diagonally over the other as before, until the sheaf is again complete, when it is bound up and removed.

To ripen the pods, many plans are adopted, a common one being to remove them to a kiln and there dry them with the heat. This, however, is a most objectionable practice, as the heat being so great, it evaporates the moisture and vital fluids from the boll very rapidly, instead of allowing them to be absorbed by the seeds in completing the remaining stages of maturity. The best system is to remove the straw, leaves, etc., from the bolls by riddling, and then, if the weather is fine, to spread them in the open air until, by a gradual process of absorption effected by the seed, the sap and moisture from the shell is thoroughly extracted, and the seeds have become ripened. If the atmosphere be damp, or if there is any appearance of rain, a barn or stoor floor, without artificial heat or of a moderate temperature, will do very well for this drying process. To extract the seeds, the bolls should be submitted to a thrashing operation, which has the effect of breaking up the husks. The seeds, then, which are found to be the heaviest and least attenuated can be selected for sowing, while the remainder can be sold to the oil mills for crushing purposes. Following the rippling, the watering steeping, or retting is the next process, and is one which requires the greatest care and experience if satisfactory results are to be obtained. The object aimed at is the decomposition of the glutinous matter which exists between and binds together the outer membrane and the inner stalk, by submersion in water for a considerable time. This operation should be conducted in the following manner: Pools from 3 feet to 3½ feet deep 12 feet broad, and 30 feet to 50 feet long, according to the requirements of the district, should be constructed near to a river if possible, so that they may conveniently be filled with water or run off when required. Where, however, the district possesses no river, the pools should be arranged near springs or wells, so that there may be no great difficulty in filling them.

When a pool has been filled, the best method of procedure is to take a sufficient number of sheaves to make one layer over the entire surface. Place the sheaves in the water in rows, in a slightly inclined position (the root ends being lowest), so that the tie of the second row will be in a line with the roots of the former one, and similarly with the others. When this has been done, then cover lightly with a layer of reeds or rushes, followed by one of sods, or, if these cannot be readily obtained, straw will serve the purpose. Over these coverings stones should then be placed of sufficient weight to keep the stalks merely under the surface of the water, and not to sink them to the bottom. In this manner the retting process can be accomplished in an average of about ten days; but, as the length of time required depends (1) on the composition of the water, (2) the condition of the atmosphere, and (3) the nature of the stalks, experience can only be relied upon to determine this point satisfactorily. A good system of testing, however, can be adopted, such as the following: When fermentation ceases, a few stalks should be removed from the pool, and the woody part broken in two places, at a few inches apart from each other; then the operator should take hold of this wood, and pull it out in a downward direction, when, if it separates freely from the fiber, it may be concluded that the operation is complete. The coverings should then be taken off and the flax removed from the pool carefully by hand, and allowed to drain and dry for a few hours preparatory to spreading. The flax water left in the pools forms excellent liquid manure, and should in every case be used for that purpose, and not run off as waste. Periodical cleanings of the pools should be carried out, so as to prevent mud and other injurious matter from accumulating in them; such cleanings also assist in reducing the obnoxious smells given out. This, however, is seldom done, and as a consequence the color of the fiber suffers more or less.—*Industries.*

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